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Metals & Mining Primer

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INDUSTRY PRIMER

Metals and Bulk Commodities

The following is a basic introduction to the underlying metals and bulk commodities affecting most of the North American metals and mining industry.

DISCLOSURE APPENDIX CONTAINS IMPORTANT DISCLOSURES, ANALYST CERTIFICATIONS, INFORMATION ON TRADE ALERTS, ANALYST MODEL PORTFOLIOS AND THE STATUS OF NON-U.S ANALYSTS. FOR OTHER IMPORTANT DISCLOSURES, visit www.credit-suisse.com/ researchdisclosures or call +1 (877) 291-2683. U.S. Disclosure: Credit Suisse does and seeks to do business with companies covered in its research reports. As a result, investors should be aware that the Firm may have a conflict of interest that could affect the objectivity of this report. Investors should consider this report as only a single factor in making their investment decision.

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Base Metals

- Aluminum
- Copper
- Nickel
- Silicon Metal
- Zinc

Aluminum

Periodic table symbol: Al

Atomic number: 13

Aluminum is the most abundant metallic element on earth, making up approximately 8% of the planet's crust. However, aluminum itself does not exist in nature as a metal. It is found in the form of bauxite, the term for the ore carrying large amounts of aluminum oxide or alumina. Although bauxite ore is relatively easy to mine, the aluminum production process is much more complex, with the current process discovered and patented by Martin Hall and Pall Heroult (the Hall-Heroult process) in 1886. This process remains the primary method used to produce aluminum. Some of the many uses of aluminum include transportation, packaging, construction, consumer durables, electrical transmission lines, and machinery.

Properties of Aluminum

Weight. Aluminum has about one-third the weight of steel but is relatively strong, offering a high strength-to-weight ratio. This helps to reduce the weight of vehicles, thus saving energy, and is one of the reasons why aluminum consumption in transportation has been the fastest growing application for the metal since 1994. In 2000, the average automobile contained 257 lbs of aluminum. By 2006, aluminum surpassed iron to become the second most used material in automobiles globally (after steel), and by 2010 the average vehicle contained 340 lbs of aluminum content.

Corrosion resistance. Aluminum is highly resistant to weather, common atmospheric gases, and liquids, holding up much better than other products such as iron (aluminum does not rust and peel off like iron, but adheres to the metal's surface).

Conductivity. Aluminum is one of the best heat and electricity conductors among the metals, with 60% of the conductivity of copper but with a much lower density. Thus, it is frequently used in power transmission lines and towers, as well as lower-voltage applications, such as appliances.

Strength. Alloys can make aluminum extremely strong, enough to compete for use in applications in place of construction steel. Additionally, aluminum's high strength-to-weight ratio makes it ideal for transportation applications.

Elasticity. Aluminum exhibits high elasticity, which reduces the load demand on foundations in structures under shock loads (both industrial and residential). This is another reason why it has been highly popular in its extruded form, in an unlimited number of shapes and construction applications.

Ease of recycling. Aluminum is very conducive to recycling, as the metal has a fairly low melting point (660 degrees Celsius), allowing for low energy requirements and high usability (virtually anything made from aluminum can be recycled).

Uses of Aluminum

Given the numerous unique properties of aluminum (strength/weight ratio, low corrosion, high conductivity, etc.), the uses of aluminum are varied and wide ranging.

Transportation. Aluminum is used extensively in automobiles, aerospace, rail, and marine applications owing to its light weight, anticorrosiveness, and strength.

Construction. Aluminum's anticorrosive nature makes it ideal for use in exterior construction products such as roofing, siding, windows, gutters, etc.

Electrical. Aluminum is used in overhead power cable wiring, transport and industrial electrical cable, power substations, and fluorescent tubes.

Packaging. One of the most common everyday uses of aluminum is in the form of beverage cans, aluminum foil, and other forms of packaging (food, cosmetics, and pharmaceuticals).

Others. Additional uses of aluminum include machinery/equipment, sports equipment, medical devices, consumer durables, and furniture.

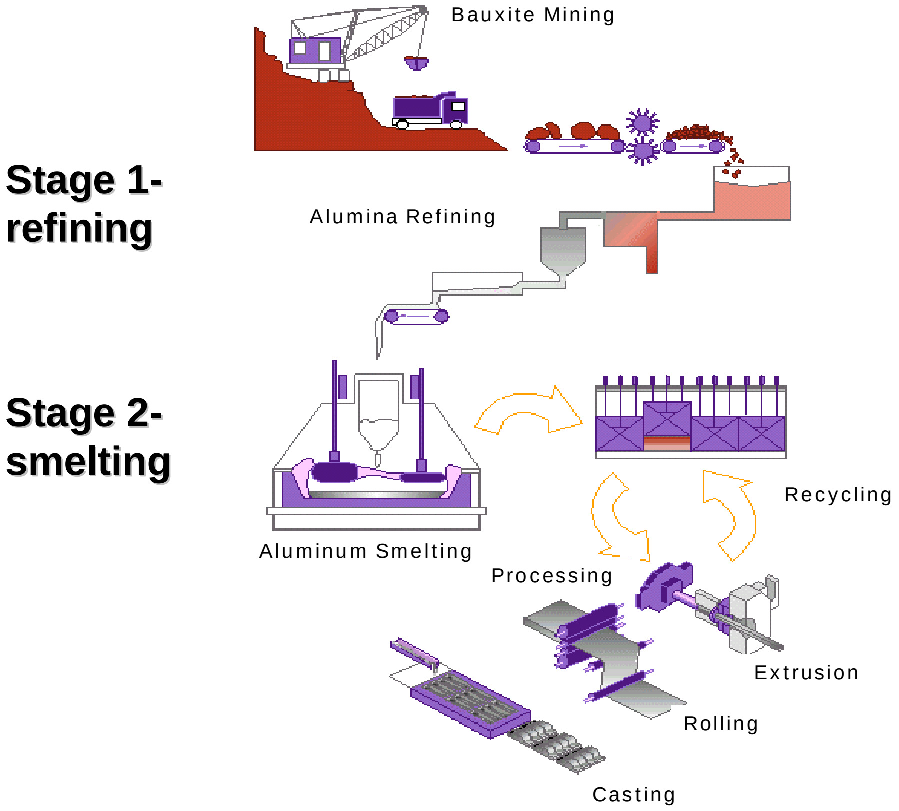
The vast range of aluminum end markets (i.e., transportation, packaging, construction, power lines, and consumer durables) means that the industry's demand growth is heavily reliant on the overall health of the economy, with aluminum shipment demand often looked at as an early indicator of an economy's health.

The Production Process

The process of making aluminum begins with bauxite mining, moves to alumina refining, and ends with aluminum smelting. The downstream businesses refer to the casting, rolling, and extrusion of the primary ingots into various end products, semis, and the use of recycling in those processes.

Normally, four to five tonnes of bauxite is used to produce two tonnes of alumina, and two tonnes of alumina is required to make one tonne of aluminum.

Exhibit 1: **Integrated Aluminum-Making Process Flow Chart**



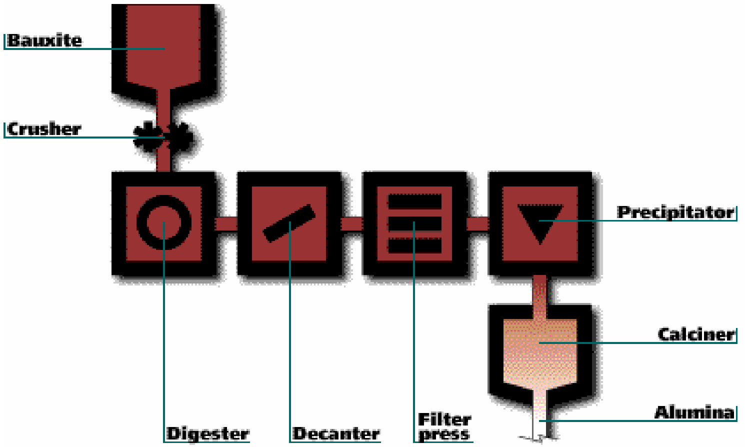
Source: International Aluminum Institute.

Stage 1: Refining

Bauxite deposits are found mostly in the tropical and subtropical regions of the world (i.e., the Caribbean, Latin America, Australia, Asia, and Africa). Bauxite ore is typically composed of 30-55% alumina and lesser amounts of iron, silicon, and titanium. As the bauxite ore is easily extracted with shovels, mining is a relatively simple process, not requiring significant blasting. (Bauxite ore is typically found close to or at the earth's surface, typically in softer earth).

The ore is then refined into alumina, typically using the Bayer process. In the first step of this process, the bauxite is crushed and mixed with lime and hot caustic soda. This solution is put through thickener tanks, resulting in a red mud mixture that sinks to the bottom of the tank. The red mud is washed with water and disposed of in tailings dams, while the solution is placed into a pressurized digester at high heat, filtered, and then cooled. What is left is a white powder (slightly finer than table salt) called alumina.

Exhibit 2: **Alumina Refinery Operations Flow Chart**

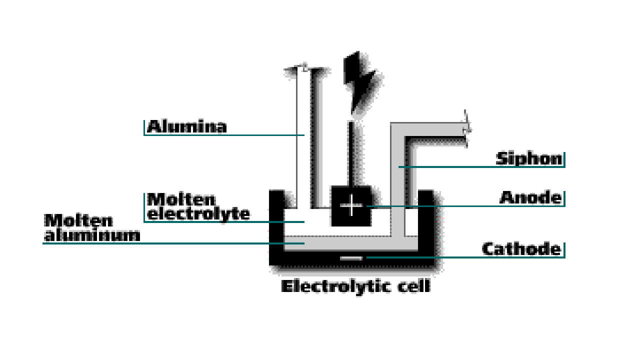


Source: MetSoc.

Stage 2: Smelting

The primary method used in smelting aluminum uses the Hall-Heroult Process, discovered and patented in 1886 and still used today. Fundamental components of a smelting operation are the electrolytic cell (or pot, which is a steel shell lined with carbon, which serves as the cathode) and the carbon electrodes that extend into the pot, which serve as the anodes. In the process, electrical currents are passed through the molten alumina, thereby removing the oxygen. This results in molten aluminum, which upon being gathered from the bottom of the cell, is degassed to remove impurities and then cast into products at the fabricating plants.

Exhibit 3: **Aluminum Smelting Process**

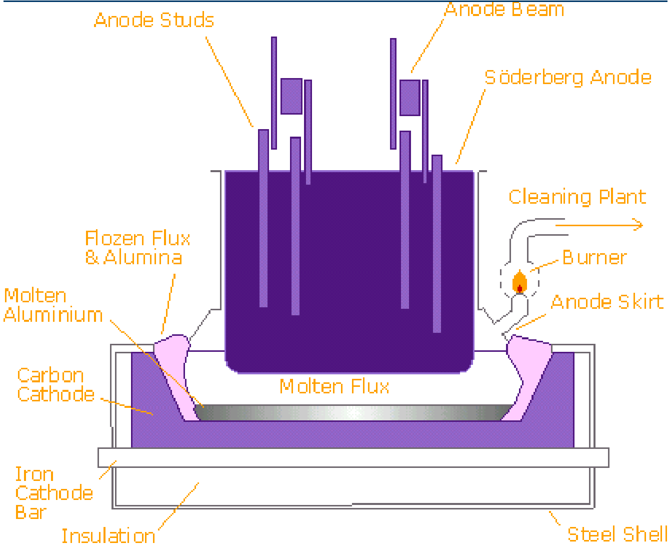


Source: MetSoc.

Soderberg Anode Cells versus Prebaked Anode Cells

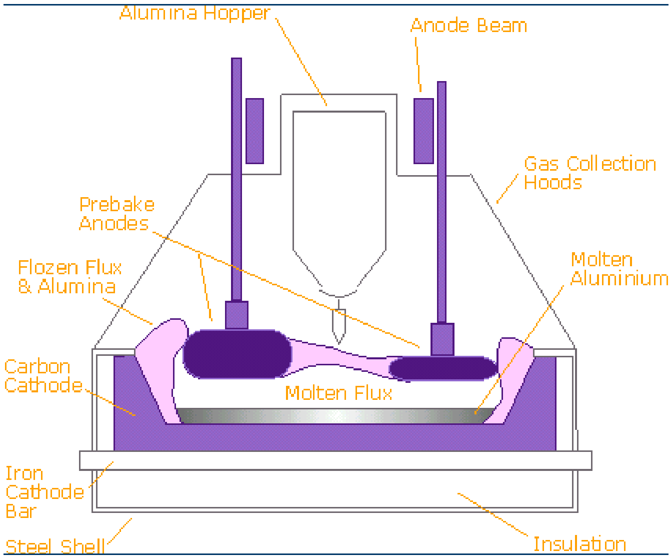
There are two basic anodes used in aluminum smelters today: Soderberg anode cells and prebaked anode cells. In general, the prebaked anode cells are primarily used in the United States and are typically preferred over Soderberg cells, as they use less electricity, are more efficient, and generally less pollutive than the Soderberg process. The majority of new smelters use prebaked anode cells, with more than 80% of current smelters using prebaked anodes.

Exhibit 4: Soderberg Cell



Source: International Aluminum Association.

Exhibit 5: Prebaked Cell



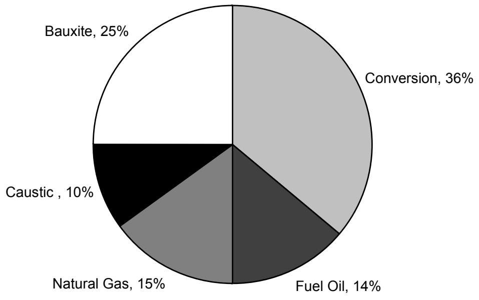
Source: International Aluminum Association.

The key distinction in Soderberg technology is the anodes; the Soderberg technology uses a continuous anode, which is delivered into the pot in the form of a paste that bakes into the cell itself, while prebake technology uses a number of prebaked recyclable anodes that are attached to rods and suspended within the cell.

Components of Production Costs

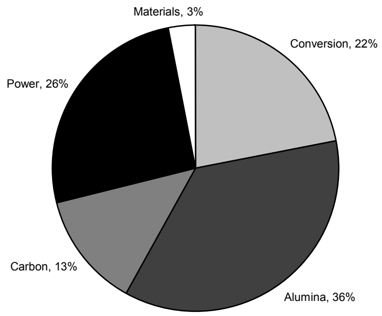
Aluminum smelting is a highly energy-intensive process, requiring approximately 13,000-15,000 kilowatt hours of electricity to make one tonne of aluminum. In terms of raw materials, on average four to five tonnes of bauxite is required to make two tonnes of alumina, while two tonnes of alumina is required to make one tonne of aluminum. As such, the major costs associated with the smelting process are alumina, electricity, labor, and other raw materials (including lime, caustic soda, and carbon pitch).

Exhibit 6: Alumina Refining Costs



Source: Alcoa, Credit Suisse estimates.

Exhibit 7: Aluminum Smelting Costs

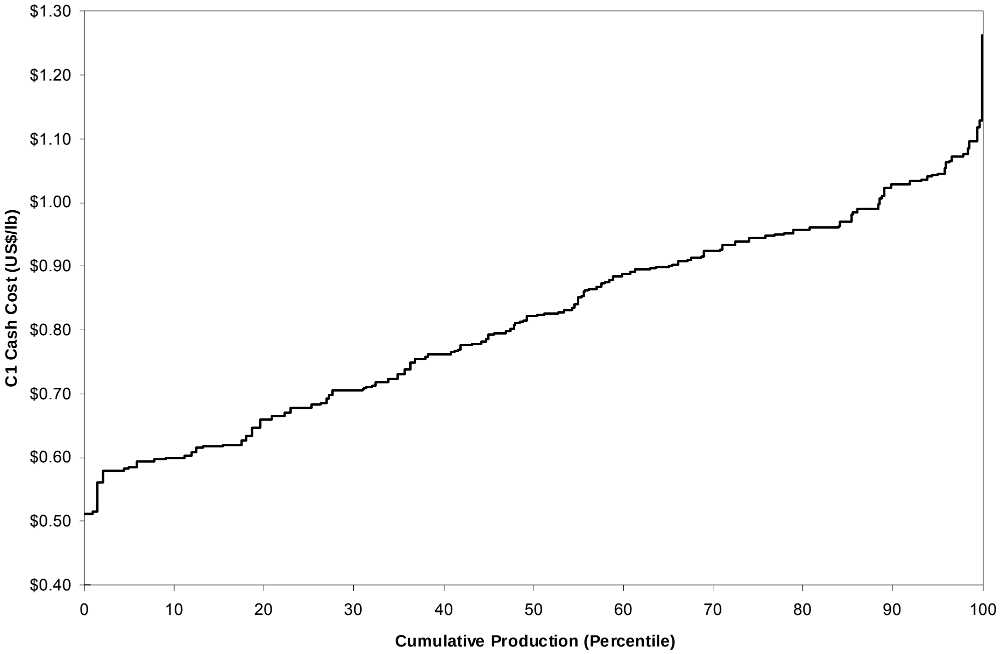


Source: Alcoa, Credit Suisse estimates.

Historically, alumina prices have been linked to the London Metals Exchange (LME) price of aluminum, in general trading anywhere in the range of 14-16% of aluminum prices. However, there is currently a push from alumina producers to de-link the price of alumina so that it prices on its own supply and demand fundamentals. While this may take a number of years to fully realize as multiyear alumina contracts slowly roll off, it should push alumina prices up closer to $400/tonne, versus approximately $350/tonne were prices to stay linked to LME aluminum.

As of Q3 2010, the average cash cost of producing aluminum was approximately $0.82/lb, with the top 15th percentile producing aluminum at $0.97/lb or higher (based on Wood Mackenzie data).

Exhibit 8: Global Aluminum Smelter Cost Curve (Q3 2010)



Source: Wood Mackenzie.

Recycling Process

Rather than producing aluminum from bauxite, recycling scrap aluminum is a significant part of the downstream aluminum products industry. Roughly 30-35% of global aluminum needs are satisfied through the recycling of aluminum. Recovering aluminum from used aluminum appliances, cans, etc. is much cheaper and more sustainable than the traditional route of producing the metal from ore. For example, recycling 1 kg of aluminum saves up to 8 kg of bauxite, 4 kg of chemical products, and 14 kilowatt hours of electricity. Recycling of aluminum products requires only 5% of the energy needed for primary aluminum production.

Virtually all products made from aluminum have the ability to be recycled into the same products for future use (i.e., beverage cans are recycled into new beverage cans, old extruded window frames can be recycled to make new windows, etc.). The Aluminum Association estimates that aluminum can recycling rates range anywhere from 25% to more than 90%, depending on the country. Recycling rates for building and transport applications range from 85% to 95% in various countries.

Global Supply

Bauxite

Guinea has the world’s largest bauxite reserves, with 27% of total reserves. This is followed closely by Australia at 23% and Jamaica at 7%.

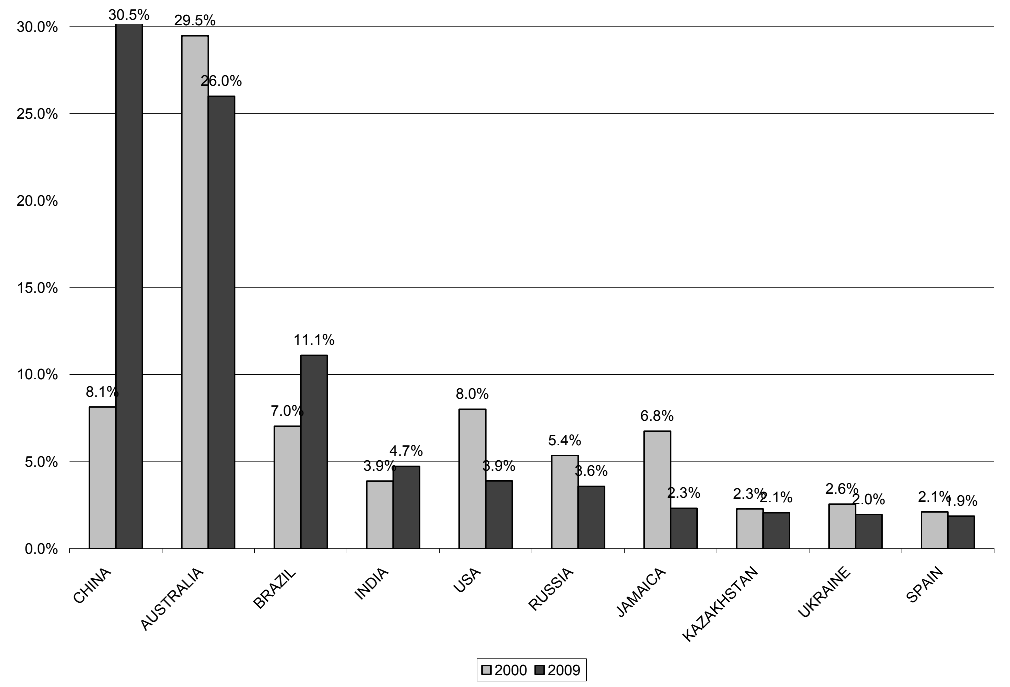
Exhibit 9: **2009 World Bauxite Reserves by Country (in 000s Tonnes)**

Country	Reserves*	% of Total
GUINEA	7,400,000	27.4%
AUSTRALIA	6,200,000	23.0%
JAMAICA	2,000,000	7.4%
BRAZIL	1,900,000	7.0%
INDIA	770,000	2.9%
CHINA	750,000	2.8%
GUYANA	700,000	2.6%
GREECE	600,000	2.2%
SURINAME	580,000	2.1%
KAZAKHSTAN	360,000	1.3%
VENEZUELA	320,000	1.2%
RUSSIA	200,000	0.7%
UNITED STATES	20,000	0.1%
OTHER COUNTRIES	5,200,000	19.3%
TOTAL	**27,000,000**	**100.0%**

**Reserves refer to material that is economically viable at the time of determination. Source: USGS.*

Alumina

Exhibit 10: **Global Alumina Production (by Country)**



Source: Wood Mackenzie.

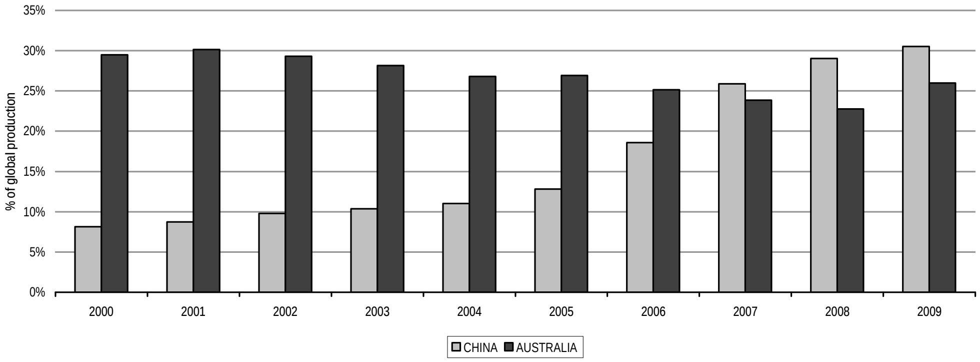
To support its growth in primary aluminum smelting, China has quickly increased its alumina production and recently surpassed Australia as the world’s largest alumina producer, despite its relatively small amount of bauxite reserves (just 2.8% of global reserves). China’s alumina production has increased almost 450% since 2000.

Exhibit 11: China Domestic Alumina Production versus Consumption (000's tonnes)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Domestic alumina production	4,339	4,733	5,480	6,180	6,985	8,536	13,740	20,900	25,137	23,792
Alumina requirements*	5,682	6,742	8,766	11,094	13,378	15,612	18,698	25,176	26,354	25,930
Aluminum production	2,841	3,371	4,383	5,547	6,689	7,806	9,349	12,588	13,177	12,965
Alumina surplus/(deficit)	**(1,343)**	**(2,009)**	**(3,286)**	**(4,914)**	**(6,393)**	**(7,076)**	**(4,958)**	**(4,276)**	**(1,217)**	**(2,138)**

**Alumina needs based on two tonnes of alumina required per one tonne of aluminum production.*
Source: Wood Mackenzie.

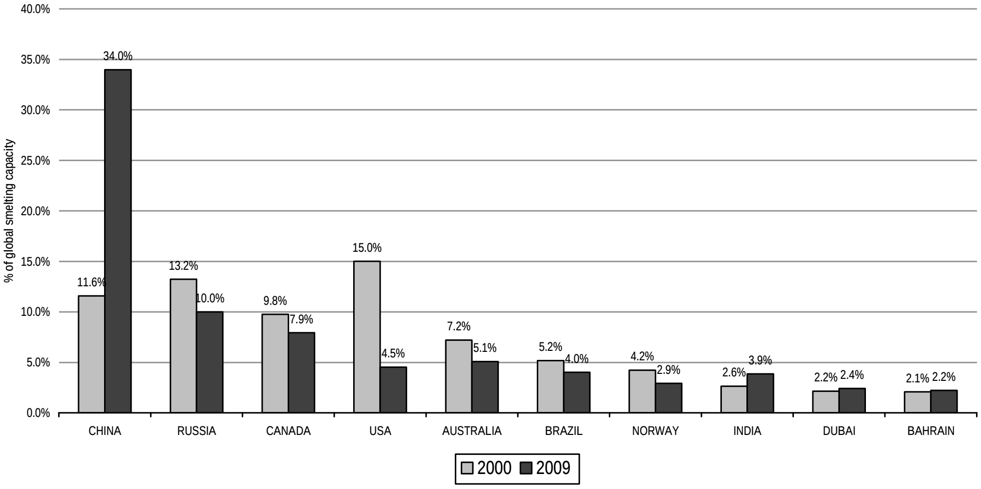
Exhibit 12: Percentage of Global Alumina Supply



Source: Wood Mackenzie.

Primary Aluminum

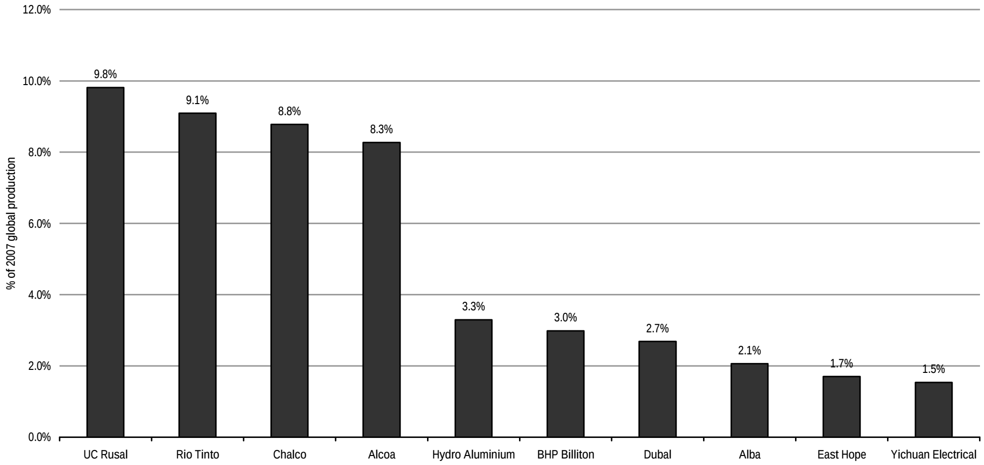
Exhibit 13: Global Primary Aluminum Production (by Country)



Source: Wood Mackenzie.

Given the high cost of electricity among most of the Western World, aluminum production has been gradually shifting away from the United States and Western Europe and into emerging regions such as India, Dubai, and Bahrain, to name a few. The exception to this is China, where aluminum production has been ramping up significantly in the past decade to keep up with the tremendous growth in metals demand, driven by the industrialization of the country. China is now the world's largest aluminum producer, with roughly 34% of total global production, versus only 11.6% in 2000.

Exhibit 14: Top Ten Primary Aluminum Producers (2009)

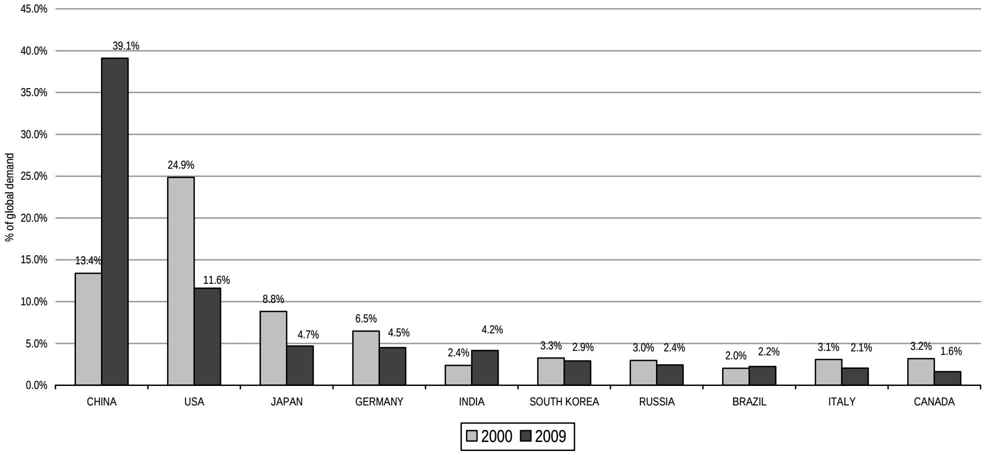


Source: Wood Mackenzie.

After significant consolidation among the top producers in 2006-07, approximately 36% of the global supply of primary aluminum is controlled by four producers: Alcoa, Rusal, Rio Tinto, and Chalco. China accounts for 34% of global output and has three of the top ten global producers.

Global Consumption

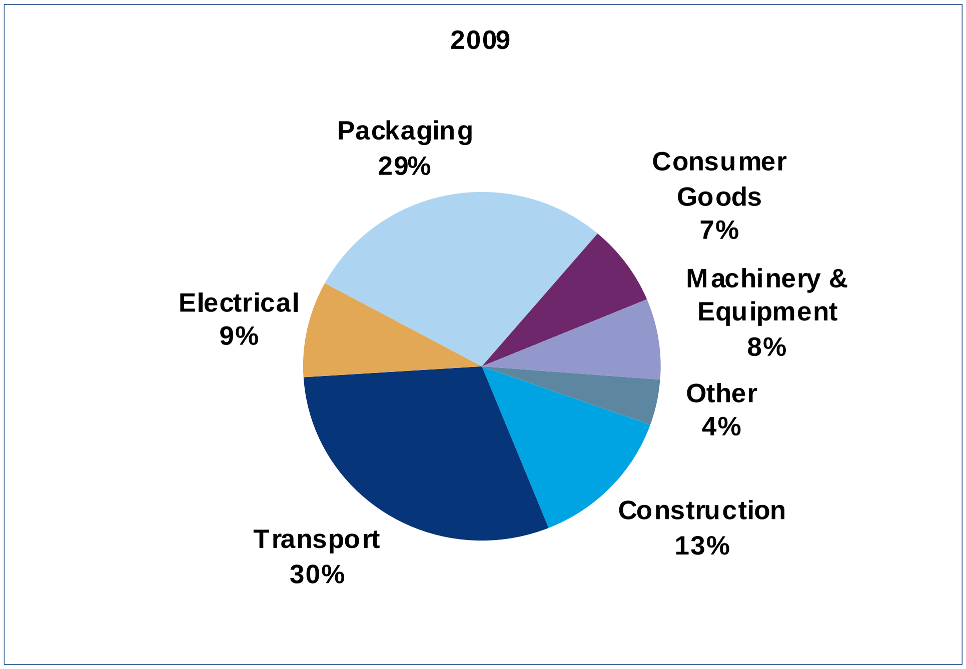
Exhibit 15: Global Primary Aluminum Consumption (by Country)



Source: Wood Mackenzie.

Since 2000, the industrialization of China has resulted in a secular shift in the percentage of global metals demand away from the Western World and into the Far East. China is now the largest consumer of base metals, accounting for 39% of aluminum demand in 2009, with the United States falling to second at roughly 12% of total demand.

Exhibit 16: **North American Aluminum Demand by End Market (2009)**



Source: Wood Mackenzie.

Transportation and packaging are the two primary end markets for aluminum. In North America, these two end markets account for almost 60% of aluminum demand, while construction and electrical make up another 22% of end-market demand.

Copper

Periodic table symbol: Cu

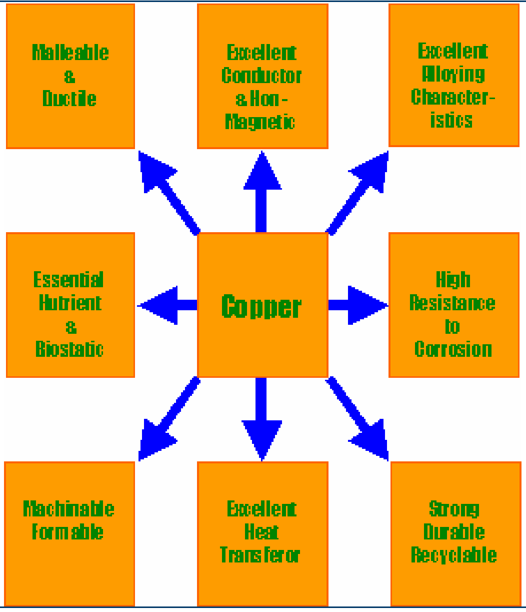
Atomic number: 29

Copper, from the Greek word *kyprios,* is one of the oldest metals known to civilization. In fact, the earliest recorded existence of known copper is around 9000 BC. However, the glorious period for copper began in the Bronze Age (possibly as early as 3900 BC), when copper was mixed with tin to create bronze, which then became heavily used in applications from construction to the production of weapons, tools, and castings. Since then, the use of copper has increased significantly and is found in a vast range of applications ranging from brass musical instruments to electrical wiring, electric dynamos, and solar cells.

Copper concentrate generally contains 25-30% copper and is the resulting product of mine ore (which typically contains less than 1% copper) once the mined ore has been crushed, milled, and concentrated. The concentrate is typically further refined and formed into cathodes, which are typically up to 99.9% pure copper, weighing up to 300 pounds. These cathodes are then shipped to mills or foundries to be formed into one of the following forms: (1) wire rod, (2) billet, (3) cake, or (4) ingot. Copper is also combined with other metals to form copper alloys, which include bronze (copper and tin), brass (copper and zinc), and copper/nickel alloys.

Properties of Copper

Exhibit 17: **Properties of Copper**


Malleable & Ductile
Excellent Conductor & Non-Magnetic
Excellent Alloying Character-istics
Essential Nutrient & Biostatic
Copper
High Resistance to Corrosion
Machinable Formable
Excellent Heat Transferor
Strong Durable Recyclable

Source: ICSG.

Corrosion resistance. Copper is resistant to weather, common atmospheric gases, and liquids, holding up much better than other products, such as iron. For example, the Statue of Liberty is made of roughly 81 tonnes of copper, with no corrosion from a century of exposure to the elements. (The light green color is a result of the natural weathering of the exterior copper covering.)

Conductivity. Copper is one of the best heat and electricity conductors among the metals (only silver is a better conductor of electricity), with roughly two-thirds higher conductivity than aluminum, although it has a much greater density. Thus, it is primarily used in power transmission lines and towers, as well as in lower-voltage applications, such as appliances.

Ductile and malleable. Copper is easily molded, shaped, and drawn into various forms, making it easy to use in a wide number of applications.

Strong and recyclable. Copper is a highly recyclable metal, with an infinite recyclable life and properties that allow for the recycling of all forms of copper (melting point at 1,356 degrees Celsius), whether in its pure state or as a copper alloy (brass, bronze, etc.). As such, copper scrap retains a high percentage of its value. While making up only 18% of global refined copper supplies in 2009, copper recycling is of significant importance in the United States, where approximately 30% of total U.S. copper supplies come from recycled copper.

Uses of Copper

Construction (includes electrical). Copper is used in a wide variety of construction applications, including plumbing, kitchen and bathroom fixtures such as taps, tubes, and fittings, heating fixtures, electrical wiring and outlets, air conditioning, and roofing. Overall, the Copper Development Association estimates that an average American home contains roughly 400 pounds of copper. Copper's high conductivity has made it the primary choice for use in power cables, transformers, building wire, and motors.

Electronics and communication. Copper is a significant raw material in electronics and telecommunications, including computers in the form of computer chips, electron tubes, data cables, and telephone wire.

Transportation. Copper is found in automobiles, usually as a copper/nickel alloy in applications such as radiators and hydraulic brakes, in addition to electrical wiring. In marine applications, copper is frequently combined with nickel to create copper/nickel alloys used for ship hulls, offshore units, desalination plants, etc., primarily owing to its resistance to seawater corrosion.

Industrial machinery and equipment. Copper is used heavily in industrial applications as an alloy, most commonly combined with tin to form bronze. Some uses include motors and wiring, heat exchangers, turbine blades, and natural gas pipes.

Consumer goods. Copper is found in a variety of consumer products as well, including microwave ovens, TV cathode rays, brass furniture and musical instruments, silverware, and coins. (Pennies are only 2.5% copper, 97.5% zinc. Nickels are actually 75% copper, while the dime, quarter, and half dollar coins contain 91.67% copper.)

Substitutability. Given the large number of similarities in physical properties (conductivity, anticorrosiveness), aluminum is commonly mentioned as a potential substitute for copper in a number of applications, including electrical wiring and home appliances. Plastics have also replaced copper in plumbing applications.

Primary Production Process

Copper ores are typically found in two forms: sulfides (roughly 80% of global copper ores) and oxides. The type of ore will dictate the method of processing, as oxide ores are typically processed using Leaching and Electrowinning (SX/EW), while sulfide ores are generally processed though smelting and refining.

A typical copper ore contains as little as 0.5-2.0% copper.

(For an animated process flow diagram provided by Minera Escondida, click the link: http://www.escondida.cl/mel/en/productive_process/processing.asp)

Mining Methods

Copper is typically mined via either an open pit or an underground mine.

Open Pit Mining

As the name implies, open pit mining is used when the ore body is near the surface. In open pit mining, the surface layer of waste rock covering the ore is removed. This exposes the ore body, which can then be easily extracted.

Underground Mining

When the ore is further below the surface, underground mining is utilized. Underground mining typically involves digging a vertical shaft into the earth up to some depth and then digging horizontal tunnels into the ore body. Given the infrastructure and equipment involved, underground copper mining is typically more expensive than open pit mining, although higher-grade material is often found at depth, which mitigates the relative cost disadvantage of underground mining.

Processing

After the ore has been mined, it needs to be processed to obtain refined copper. There are primarily two broad routes of producing copper from copper ore: (1) the *pyrometallurgical* route and (2) the *hydrometallurgical* route. As the names suggest, the pyrometallurgical route involves very high temperature smelting, while the hydrometallurgical route works with aqueous solutions. The pyrometallurgical route currently accounts for roughly 75% of world copper production from copper ores.

Copper Production by the Pyrometallurgical Route (Smelting and Refining)

In the pyrometallurgical route (which is not typically used for oxide ores), the ore is first crushed and ground to a fine powder. This powder is mixed with water to form slurry. Certain chemicals that coat the copper minerals are added to the slurry and air is passed through the material. The rising bubbles capture the coated mineral particles and float them to the surface (froth-flotation process). The floating mineral is then skimmed and dried. This dried material is called copper concentrate and typically contains about 25-35% copper and a similar quantity of sulfur (the percentages vary depending on the ore that is used).

The concentrate is passed through a series of high-temperature processes of roasting and smelting. These processes essentially oxidize the sulfur and other impurities in the ore and produce copper of about 99.0% purity. This copper often contains trapped gases (mainly sulfur dioxide). As the molten copper cools, these gases escape and make blister-like marks on the surface of the metal. This metal is called blister copper.

Although 99.0% purity is a great improvement from the original grade of about 1% copper in the ore, it is not good enough. Even 1% of impurities in copper can significantly deteriorate its conductivity and other properties. Copper needs to be refined further through electrorefining. In electrorefining, 99.0% purity copper (anode) is immersed in an acid bath. As electric current is passed through the solution, two simultaneous processes take place. At the anode, copper dissolves into the solution, while at the cathode, pure copper is deposited. This results in more than 99.9% pure copper deposited at the cathode.

This whole process results in significant sulfur dioxide generation. (The process produces more sulfur dioxide by weight than the copper it produces.) In the past, this gas used to be dumped into the environment. But in the current regulatory environment, that is often not possible. Therefore, most of this sulfur dioxide is converted into sulfuric acid. The acid thus produced can either be used as a leaching agent in a related hydrometallurgical process (described later) or sold (at times at a loss because the price of sulfuric acid may not cover even transportation costs from remote mining locations to the nearest market).

Copper Production by the Hydrometallurgical Route (Leaching and Electrowinning, or SX/EW)

The first step in the hydrometallurgical route involves leaching the ore. Leaching essentially means dissolution of the copper ore in sulfuric acid. (Bacterial and alkaline solutions can also be used in some cases.) Acidic leaching is typically the most effective for oxide ores. Sulfide ores are typically first oxidized by bacterial leaching. The leaching process (especially bacterial leaching) can be extremely slow and may take months or even years if not modified. Using smaller crushed ore particles, more concentrated acid, higher temperature, and pressure are some of the methods typically used to accelerate the process. However, these modifications may significantly increase the cost of production.

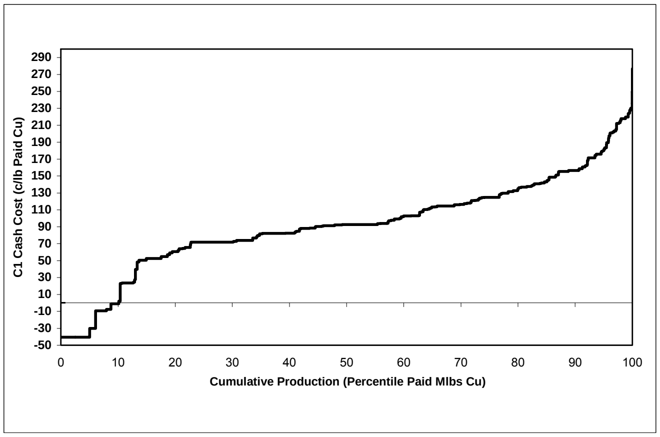
Leaching of ore results in a copper sulfate solution (with other impurities), which is then contacted with an organic solvent in the solvent extraction (SX) stage. In the SX stage, copper is extracted from the aqueous solution, and most of the other impurities remain in the leach solution. A strong acidic solution is used to strip the copper from the organic solvent.

The resultant purer copper sulfate solution goes to the electrowinning (EW) stage, where it is electrochemically purified. The pure copper forms at the cathode, and it is as pure or purer than copper produced by electrorefining of blister copper. The hydrometallurgical route of producing copper is more environmentally friendly, uses less energy, and can be used with ores with much lower grades. The process is less capital intensive than the pyrometallurgical route and hence can be used when the ore body is not big enough to justify the capital costs of the smelting route. However, recovery rates of copper for SX/EW are typically lower when compared with the smelting/refining method, which is offset by the fact that the SX/EW process is typically lower cost.

Production Costs

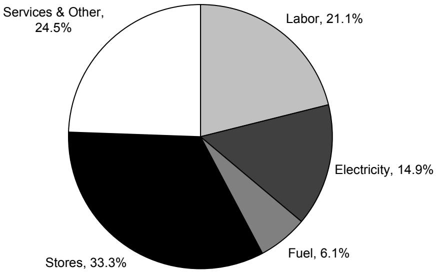
As of Q3 2010, the average cash cost of producing copper was approximately $0.93/lb, with the highest 10% of global supplies produced at $1.55/lb or higher (based on Wood Mackenzie cost data). The direct costs of mining are broken out in Exhibit 19 . Labor accounts for approximately 21% of total mining costs on a global basis, while fuel and electricity account for approximately 15% of production costs in total.

Exhibit 18: **2010 Global Cost Curve**



Source: Wood Mackenzie, Credit Suisse estimates.

Exhibit 19: **Copper Mine Site Production Costs by Type (2010E)**



Source: Wood Mackenzie, Credit Suisse estimates.

Stores includes items such as spare parts and consumables, while Services covers costs such as water, drilling, security, and food/housing.

Global Supply

Major Copper Producers

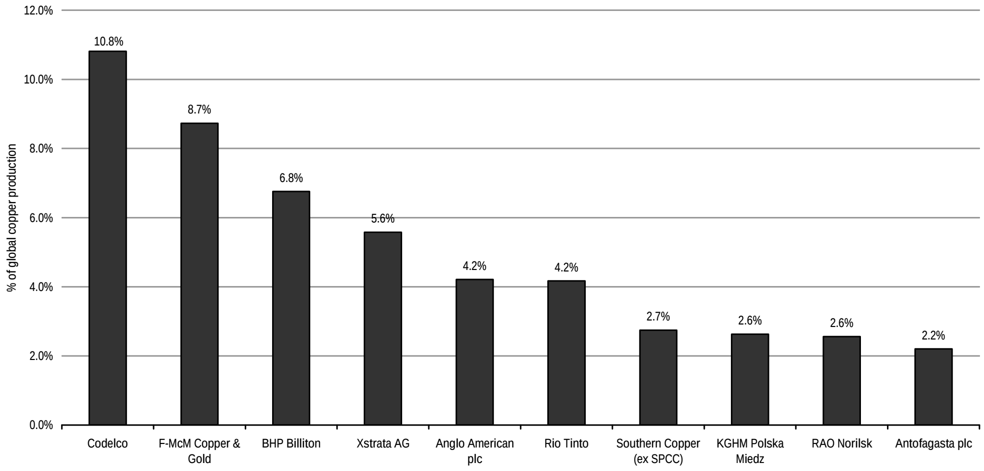
Copper is a high value-by-weight metal (compared with steel), and hence it is economically transportable, with essentially a global supply chain. Since the average grade of copper ore is approximately 1%, it is uneconomical to transport the ore without processing. Typically, the ore is processed and converted into concentrate near the mine site; however, copper concentrate is also traded widely through spot and contract markets.

A large number of producers have surplus mining capacity, as compared with smelting capacity. For example, Codelco, the world's largest copper miner, has smelting capacity for roughly 65% of its 2010 mine production.

An interesting dichotomy in the copper industry lies in the fact that the mining companies control a large proportion of the resources, while many smelters are standalone entities without access to the copper ores. Further, the cost involved in mining and concentration of the ores is significantly higher than the cost of smelting and refining the ores. Given the separation of ownership between the miners and the smelters, treatment and refining charges (TC/RC's) paid by the miner to the smelters are typically negotiated annually. These annual smelting and processing fee agreements are often viewed as an indicator of the relative availability of upstream mine supply, with low smelting fees typically indicating tight supplies of concentrates available to the smelters.

Exhibit 20 and Exhibit 21 display the major miners and smelters in the copper market.

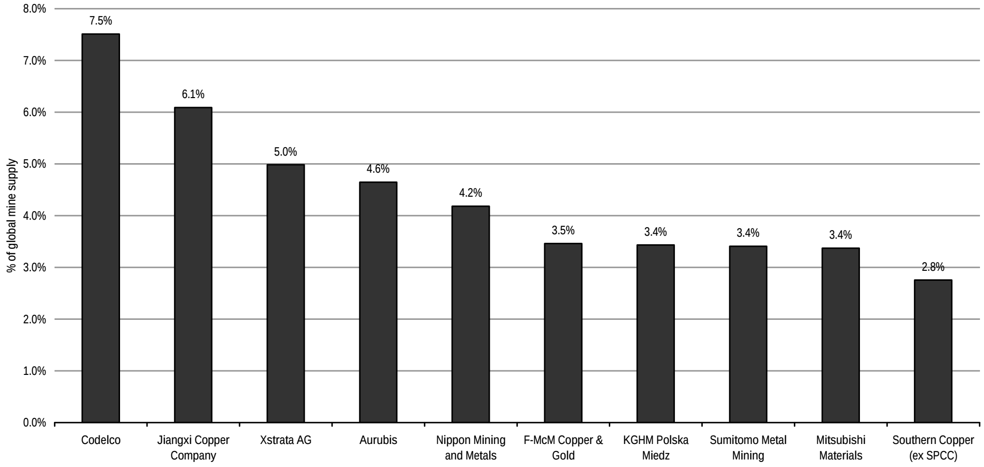
Exhibit 20: **Top 10 Copper Miners (2010E)**



Source: Wood Mackenzie, Credit Suisse estimates.

Chilean state-owned copper producer Codelco is the world's largest copper miner, with roughly 10%-plus of global copper production. The merger between Freeport-McMoRan Copper & Gold and Phelps Dodge created the world's second largest copper producer, accounting for approximately 9% of global supplies.

Exhibit 21: **Top Ten Copper Smelters (2010E)**

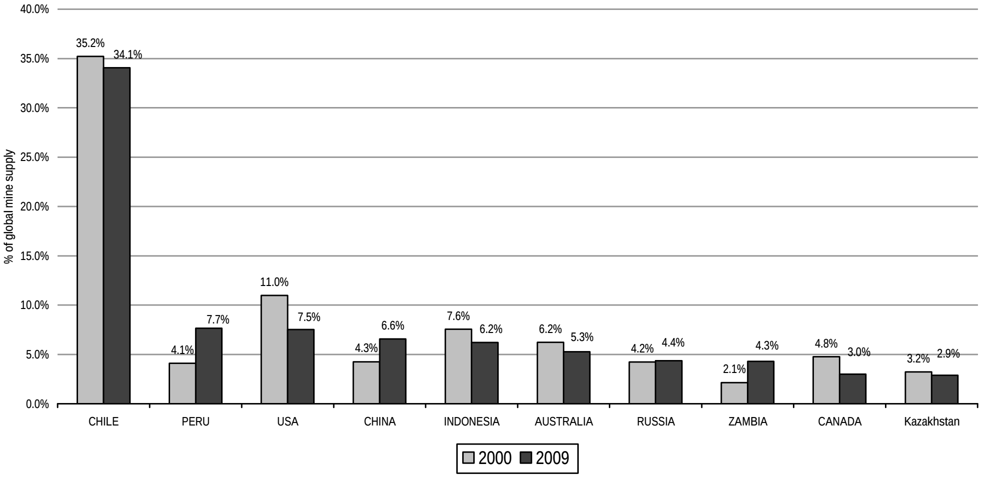


Source: Wood Mackenzie, Credit Suisse estimates.

Roughly one-half of the top players in the smelting and refining business are not among the top copper miners, as marginal value creation and low margins make the smelting business less attractive for miners. As such, smelters tend to be located close to their end markets or in areas with lower relative power costs.

Major Producing Regions

Exhibit 22: **Global Copper Mine Supply (by Country)**

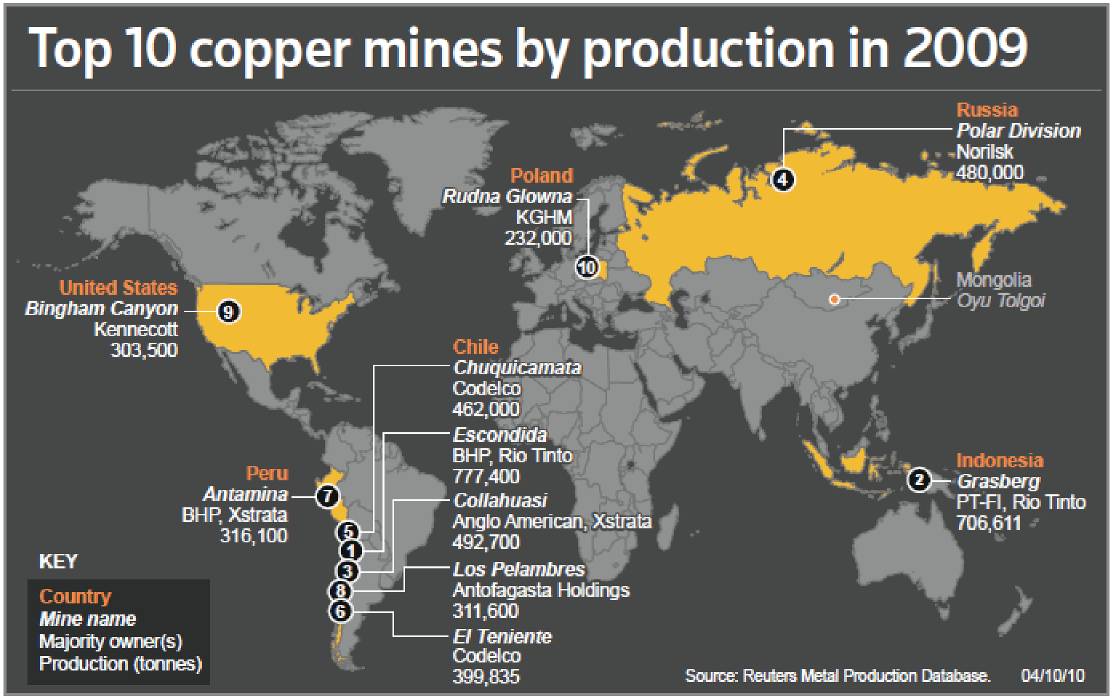


Source: Wood Mackenzie, Credit Suisse estimates.

Chile remains the dominant copper-producing nation, accounting for approximately 34% of global mine supply. As can be seen in Exhibit 23: Top Global Copper Mines (2009), Chile has five of the top ten largest mines globally.

We expect a gradual regional shift away from current mining areas to newer regions where the bulk of exploration and development is concentrated, including the Democratic Republic of the Congo, Zambia, and Mongolia.

Exhibit 23: **Top Global Copper Mines (2009)**



Source: Reuters.

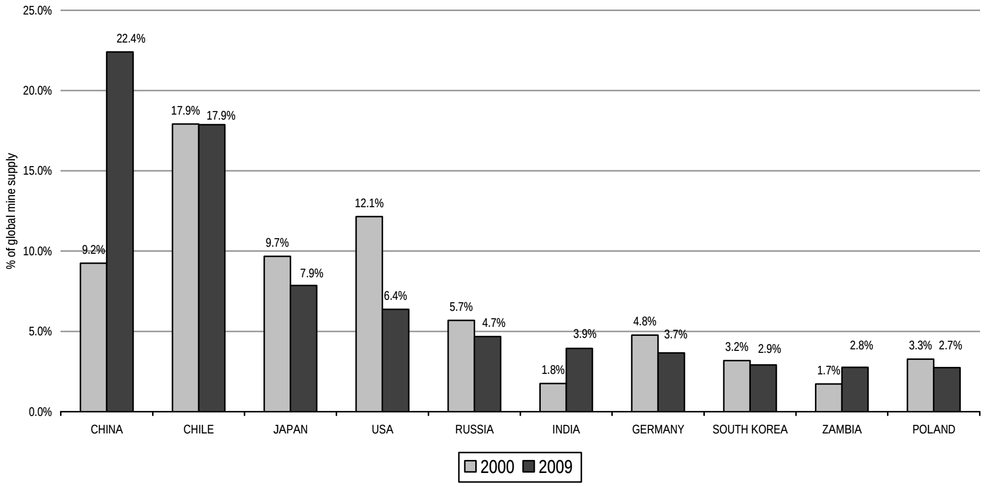
Exhibit 24: 2009 World Copper Reserves by Country (in 000s tonnes)

	Reserves*	% of Total
CHILE	160,000	29.6%
PERU	63,000	11.7%
MEXICO	38,000	7.0%
UNITED STATES	35,000	6.5%
INDONESIA	31,000	5.7%
CHINA	30,000	5.6%
POLAND	26,000	4.8%
AUSTRALIA	24,000	4.4%
RUSSIA	20,000	3.7%
ZAMBIA	19,000	3.5%
KAZAKHSTAN	18,000	3.3%
CANADA	8,000	1.5%
OTHER COUNTRIES	68,000	12.6%
TOTAL	**540,000**	**100.0%**

**Reserves refer to material that is economically viable at the time of determination. Source:USGS.*

The biggest reserves of copper globally are located in Chile, Peru, Mexico, and the United States, with the development of emerging regions such as Mongolia and the Congo increasing in importance. Chile has the world's largest copper reserves, accounting for almost 30% of the world's total economic reserves. This dwarfs the United States, which has the fourth largest reserves at 6.5%.

Exhibit 25: Global Refined Copper Supply (by Country)

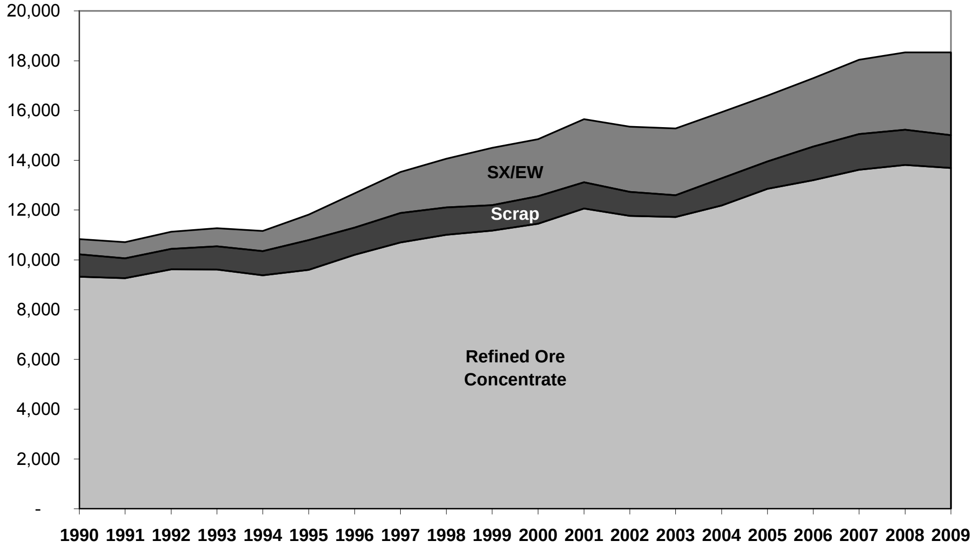


Source: Wood Mackenzie, Credit Suisse estimates.

While Chile still refines a substantial portion of the world's copper (given its predominance as the world's largest copper miner), refined copper production is sourced closer to the end markets, with China now the largest producer of refined copper globally. This is primarily driven by the economics; i.e., it is feasible to transport copper concentrates from distant mine locations to the smelters, while adding only a small amount to the landed cost. This makes it possible for the smelters and refiners to be located closer to the end consumers. As such, Chinese smelting capacity has more than doubled over the past decade, while that of the United States has fallen by approximately 45%, with the focus of the smelting operations having shifted over the past decade from the Americas to Asia.

Breakdown of Global Supply

Exhibit 26: Makeup of Global Copper Supply (000's tonnes)



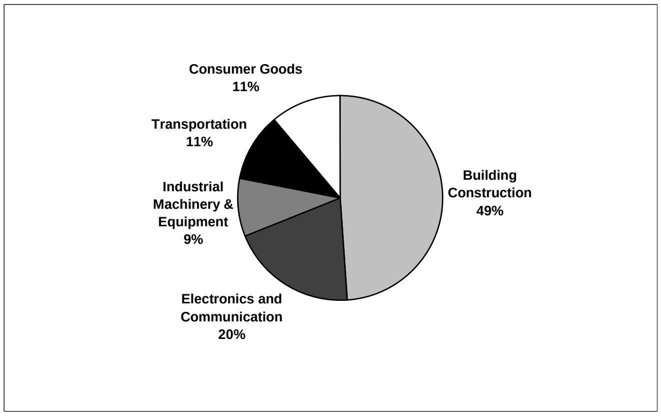
Source: Wood Mackenzie, Credit Suisse estimates.

While refined ore still accounts for the bulk of global copper supplies (83%), SX/EW-based copper production (which accounts for 17% of global copper supplies) has been the fastest growing source of copper supplies, increasing by an average of almost 10% per year since 1990, versus average annual growth of 2% for refined ores (although SX/EW growth has dropped to an average of 4% since 2000, versus 2% for refined ores over the same period).

Global Consumption

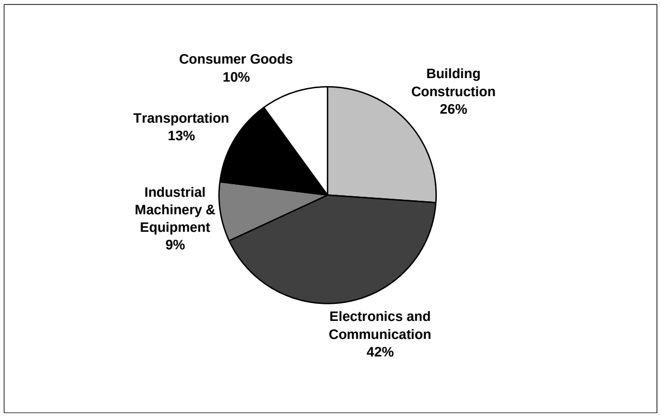
Differences in Copper Demand among Regions

Exhibit 27: Copper Consumption in the United States



Source: Wood Mackenzie.

Exhibit 28: Copper Consumption in China

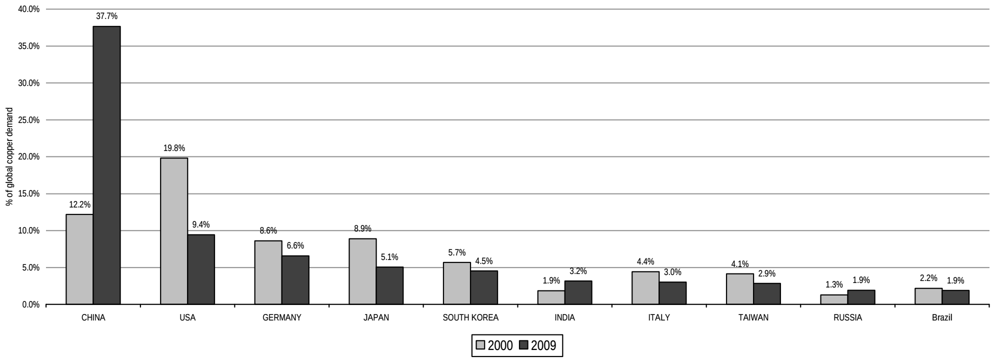


Source: Wood Mackenzie.

Globally, the major end markets for copper have been construction and electronics, accounting for more than 60% of the global copper demand. However, regional variations in the end use of copper continue to exist. For instance, in the United States, 49% of copper consumption is by the construction sector, whereas in China the dominant use for copper is in the electronics and communication sector, which takes 42% of total copper consumption.

Copper Consumption by Region

Exhibit 29: Global Copper Consumption (by Country)

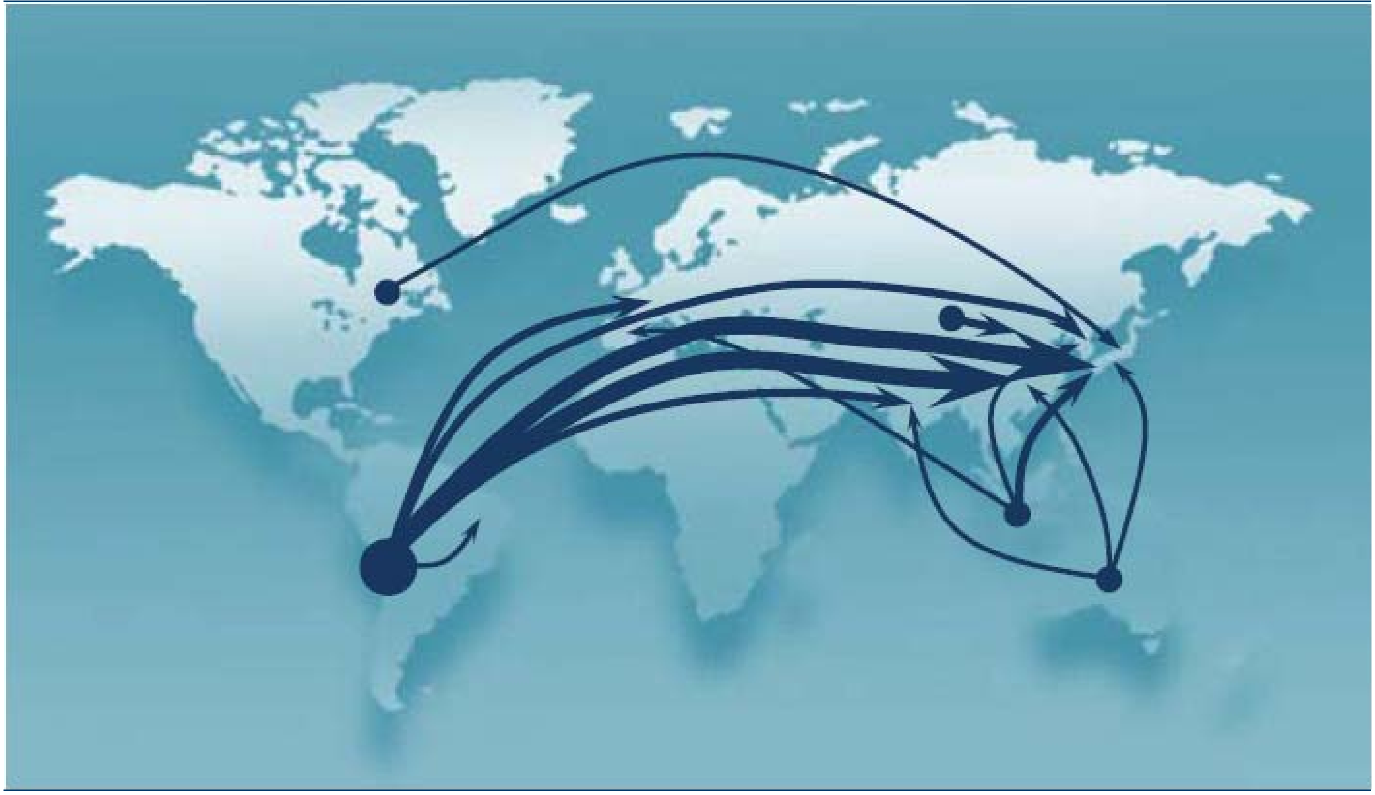


Source: Wood Mackenzie, Credit Suisse estimates.

China is the leading copper-consuming nation in the world, accounting for approximately 37.7% of global demand, higher than the United States (9.4%).

Global Trade in Copper

Exhibit 30: Trade Flow of Copper Ores and Concentrate



Source: International Copper Study Group 2010 Factbook.

The global trade in copper can be divided into trade in concentrates and trade in the metal. While concentrate flows originate in the Latin American countries (Chile and Peru) and North America, the copper metal trade flows are dominated mainly by exports to Asia. Regions with a copper surplus such as the Commonwealth of Independent States (CIS, formerly the U.S.S.R.), North America, and Latin America export copper in large quantities to the copper-short Asia region.

Nickel

Periodic table symbol: Ni

Atomic number: 28

Nickel, discovered in 1751, is a lustrous, silvery white metal. Nickel is common and widely distributed. On average, the earth's crust contains just about 0.0075% nickel. Taking the entire earth into consideration (including the mantle and core along with the crust), nickel is the fifth most common element. Nickel's economic utility lies not in its standalone usage, but in its excellent alloying characteristics.

Properties and Uses

Nickel has a melting point of 1,453 degrees Celsius, moderate thermal and electrical conductivity, high resistance to corrosion and oxidation, and high strength and toughness even at higher temperatures. It is the properties of corrosion, temperature resistance, and high strength that make nickel a highly valuable addition in many alloys. Reflecting these qualities, nickel is widely used in a variety of products ranging from consumer, industrial, military, transport/aerospace, and marine to architectural applications. The public may recognize nickel in coins, as it is used for this purpose in pure or alloy forms by many countries, or as bright and durable electrolytically applied coatings on steel (nickel plating). The biggest use, however, is as an alloying metal along with chromium and other metals in the production of stainless and heat-resisting steels. These are mostly used in industry and construction, but also for products in the home such as pots and pans and kitchen sinks.

Approximately 65% of nickel is used for manufacturing stainless steel, and another 22% is used to manufacture other ferrous and nonferrous alloys (including super alloys), which are used for various specialty applications. About 9% is used in plating and 6% in other uses, including coins and a variety of nickel chemicals.

Nickel processed directly from mineral deposits is referred to as primary nickel, while nickel that has been previously used in consumer and industrial applications is called secondary nickel. Most of the nickel recycled is in the form of nickel-bearing stainless steel. Nickel's resistance to corrosion, high strength over a wide temperature range, pleasing appearance, and suitability as an alloying agent make it useful in a wide variety of applications.

There are several grades of stainless steel, each with slightly different properties and alloy content. The main alloying element in stainless steel is chromium that provides basic corrosion resistance. Stainless steel is defined as steel containing a minimum of 10% chromium. The various types may be subdivided into four main groups: ferritic, austenitic, martensitic, and duplex stainless steels.

Exhibit 31: Types of Stainless Steel

Grade	UNS No.	Family	Cr[c]	Ni[c]	Mo[c]	N[c]	C(max)	Other[c]	PRE[c, e]	Yield strength MPa (min)[b]	Tensile strength MPa (min)[b]	Elong % (min)[b]
430	S43000	ferritic	17				0.12		17	205	450	22
420	S42000	martensitic	13				0.15 min		13	1480[c]	1720	8[c]
304	S30400	austenitic	18	9			0.08		18	205	515	40
304 ½ hard										760	1035	7
304L	S30403	austenitic	18	9			0.03		18	170	485	40
316	S31600	austenitic	17	11	2.1		0.08		24	205	515	40
316L	S31603	austenitic	17	11	2.1		0.03		24	170	485	40
904L	N08904	austenitic	20	25	4.5		0.02	1.5Cu	35	220	490	35
2205	S31803 S32205	duplex	22	5	3	0.15	0.03		34	450	620	25
17-4PH	S17400	precipitation hardening	16	4			0.07	4Cu 0.3Nb	16	1170	1310	10-May
Alloy 254	S31254	super[d] austenitic	20	18	6	0.2	0.02	0.75Cu	43	300	650	35
Alloy 2507	S32750	super[d] duplex	25	7	4	0.28	0.03		42	550	795	15

a 0.2% proof stress

[b] Annealed condition except for grades 420 and 17-4PH which have been heat treated and 304 ½ hard which has been cold worked, the intention in each case being to increase strength and hardness

[c] Typical values

[d] The term "super" is commonly used when the PRE number of the alloy is 40 or more

[e] PRE = Pitting Resistance Equivalent (see text)

Source: AISI, Credit Suisse estimates.

Ferritic stainless steels, which represent 22-25% of total stainless steel production, contain little or no nickel. These stainless steels have fair to good corrosion resistance, particularly to chloride stress corrosion cracking. They are magnetic and are not hardened by heat treatment.

Austenitic grades represent about 74% of total world stainless steel production. The most commonly used austenitic grade of stainless steel is grade 304, which contains 8.0-10.5% nickel and 18-20% chromium and is frequently referred to as 18/8 grade. There are a variety of variations of grade 304 that have been developed for more specialized applications. These variations may involve the specification of lower carbon content or the addition of other alloying elements such as copper or titanium. Variations of grade 304 may be used in a wide range of applications, from cutlery to pharmaceutical plant equipment. In more aggressive environments, such as acids or seawater, higher corrosion resistance is required.

Primary Production Process

Nickel occurs in nature principally as oxides, sulfides, and silicates. Ores of nickel are mined in about 20 countries on all continents and are smelted or refined in about 25 countries. Primary nickel is produced and used in the form of ferronickel, nickel oxides and other chemicals, and as more or less pure nickel metal. Nickel is also readily recycled in many of its applications, and large tonnages of secondary or scrap nickel are used to supplement newly mined metal.

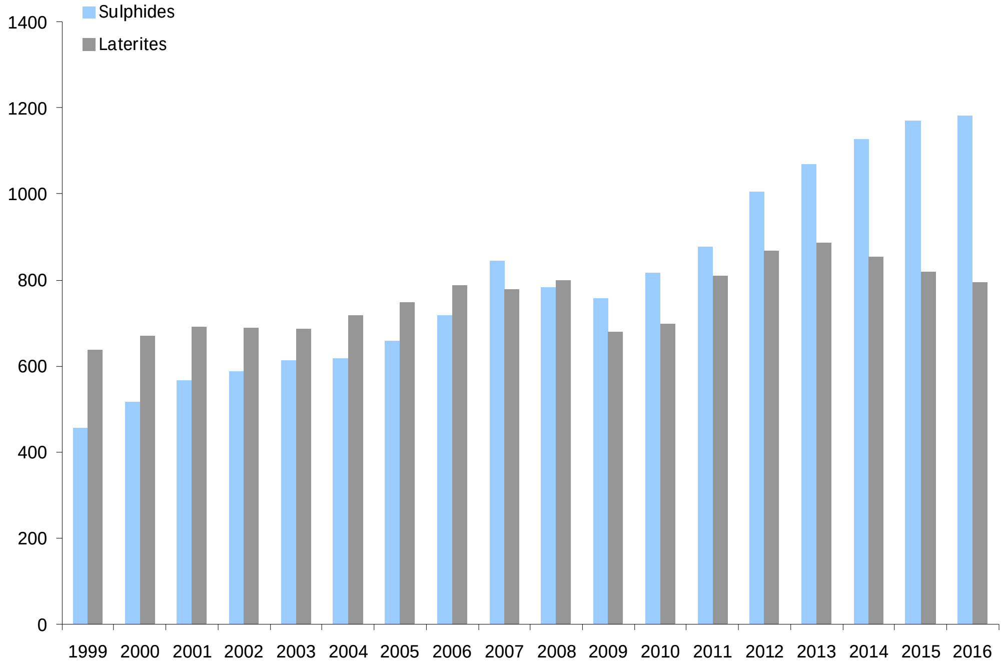
The primary extraction processes can be simply defined as the processes that receive nickel concentrate or prepared ore to produce final metal products, ferronickel, and nickel oxide, as well as intermediate products such as matte and liquor.

Primary nickel extraction is carried out by two main methods:

- Pyrometallurgical methods: typically used with sulfides
- Hydrometallurgical methods: typically used with laterites

Nickel ores can be broadly classified into two types: sulfide ores, which are predominantly extracted through underground mining, and lateritic hydrous ores, which are mainly surface mined. Pentlandite (NiFe) is the principal sulfide nickel ore, and it often occurs along with iron and copper deposits. Limonite and garnierite are the major lateritic ores and contain elements such as iron, magnesium, and silica.

Exhibit 32: Total Nickel Production (Sulphides versus Laterites)



Source: Brook Hunt, Credit Suisse estimates.

Nickel sulfides are treated primarily by pyrometallurgy. For most of the sulfide ores, a part of the refining and smelting process is devoted to separation of copper and iron from nickel. Ore is concentrated through physical means, which includes floatation and magnetic separation. A process of roasting, smelting, and converting is used to remove sulfur and iron from sulfide ores. After roasting, the nickel matte consists primarily of nickel subsulfides. Depending upon the final need, the matte is processed further. For example, nickel sulfides can be roasted to yield nickel oxide, which can be used directly in steel production; alternatively, electrochemical, carbonyl process, or pyrometallurgical refining kiln reduction can be used to extract refined nickel.

Lateritic ores are not very amenable to physical concentration, and these ores are concentrated through a chemical leaching process. Nickel ores typically have an initial concentration of 1-3%. Lateritic ores can be processed through both the hydrometallurgical and pyrometallurgical routes.

Pyrometallurgical smelting of nickel oxide ores typically poses design and operational challenges, including the requirement of a large amount of energy. Instead, sulfur is generally blended with the oxide furnace product to produce iron-nickel matte. The smelting process is used to further yield a ferronickel alloy, which contains less than 50% nickel content and can be used directly in steel making.

Hydrometallurgy of oxidic ores involves process routes to produce nickel cobalt liquor or nickel cobalt sulfide. Nickel cobalt liquor is produced by drying and grinding, reducing, and then leaching (with ammonia) an oxidic concentrate. Nickel cobalt liquor can then either be precipitated by sulfiding, or the nickel and cobalt can be separated by solvent extraction, which is then further processed by electrowinning into refined nickel.

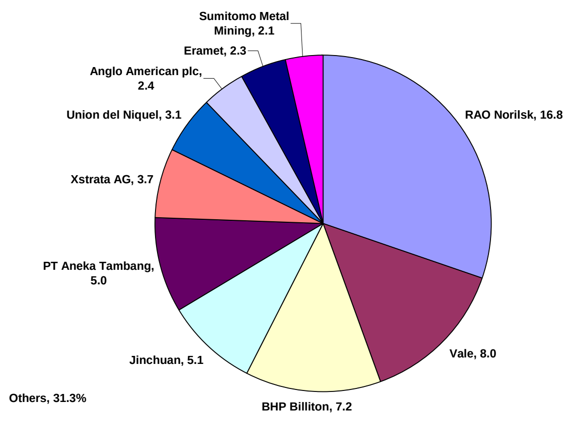
Hydrometallurgy has been used to extract nickel for many years, but it has only been since the mid-1990s that successful acid oxidative hydrometallurgical technology has been developed for a wide range of nickel reserves. In 1998, three manufacturers started facilities in Australia for hydrometallurgical processing of nickel ore through pressure leaching. However, these plants have faced a number of technological problems. CVRD Inco seems to have fared the best in this area and commenced production at Voisey's Bay partly utilizing this type of technology. Hydrometallurgical processing can accommodate a number of different ore bodies that are not conducive to pyrometallurgical processing. Hydrometallurgical processing can also extract a higher portion of nickel content and be more energy effective. We feel this is a particular area where technological advances can be made and provide a comparative advantage through lower operating costs.

One of the more interesting hydrometallurgical processes is called Activox, which was initially developed in the early 1990s to recover gold from refractory sulfide gold concentrates. In 1997, Tati approached Western Minerals Technology (WMT) and expressed interest in the Activox process to treat the low-grade nickel sulfide concentrates at the mine. Subsequently, the Tati Hydrometallurgical Demonstration Plant (HDP) was developed to reduce the risk of installing a full-scale Activox refinery. The Activox process involves a combination of fine grinding followed by a low-temperature (100-110 degrees Celsius) and low-pressure (1,000 kPa) oxidation leach circuit. Activox offers potentially comparable results compared with other competing technology such as pyrometallurgical smelting but differs with the mild process conditions, resulting in a simpler and scalable design, which is easier to operate and can be installed at a lower capital cost.

Global Mine Supply

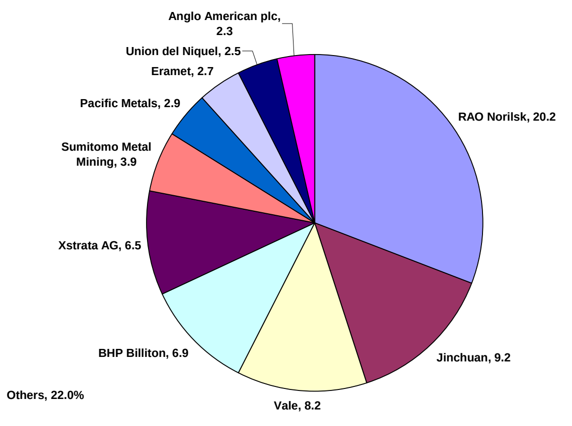
The top ten miners produce 69% of mined nickel production and nearly 78% of refined nickel. The global shortage of credit has significantly reduced the demand for nickel, which has put downward pressure on the price of nickel, which in turn has caused a reduction in output or temporary closures of nickel mining. Approximately 140kt of global nickel mine supply was removed.

Exhibit 33: **Top Ten Mine Nickel Producers**



Source: Brook Hunt, Credit Suisse estimates.

Exhibit 34: **Top Ten Refined Nickel Producers**

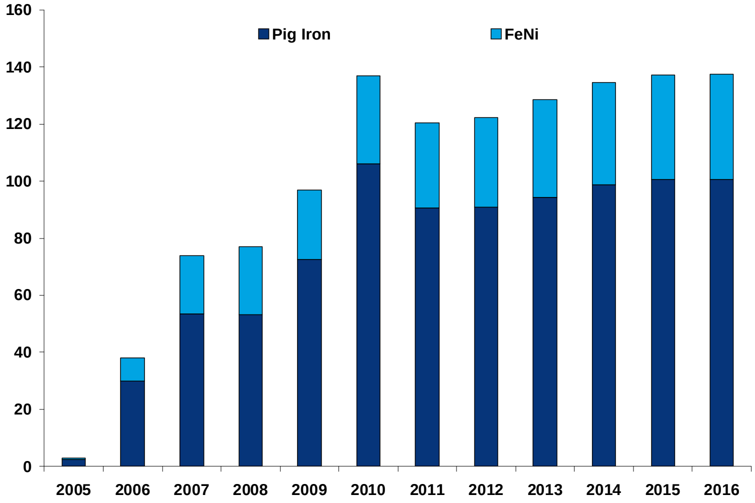


Source: Brook Hunt, Credit Suisse estimates.

After two years of supply contractions in 2008-09, global refined nickel output has returned to growth and is expected to increase 5% in 2010 to 1.4Mt. World mined nickel production will rise by 6%, to around 1.52Mt.

Laterite nickel ore accounts for about two-thirds of the world's nickel resources but is generally not used for producing refined pure nickel because of its low nickel content that ranges between 1% and 2%. After a series of sintering and smelting processes, removing impurities such as phosphorus, sulfur, and silicon to specification, the laterite nickel ore can be processed into nickel pig iron that contains 4-13% nickel, with iron and other metals accounting for the balance. Chinese stainless steel producers use nickel pig iron, to which they add chromium and other materials, to produce 200 and 300 series stainless steel, which accounts for more than 70% of total stainless steel production in China. Chinese domestic growth demand for nickel and nickel pig iron will far exceed the increase in production of nickel in China over the next few years. With the Chinese Government Steel Industry Restructuring Program, many nickel pig iron producers have been shut down owing to poor environmental standards.

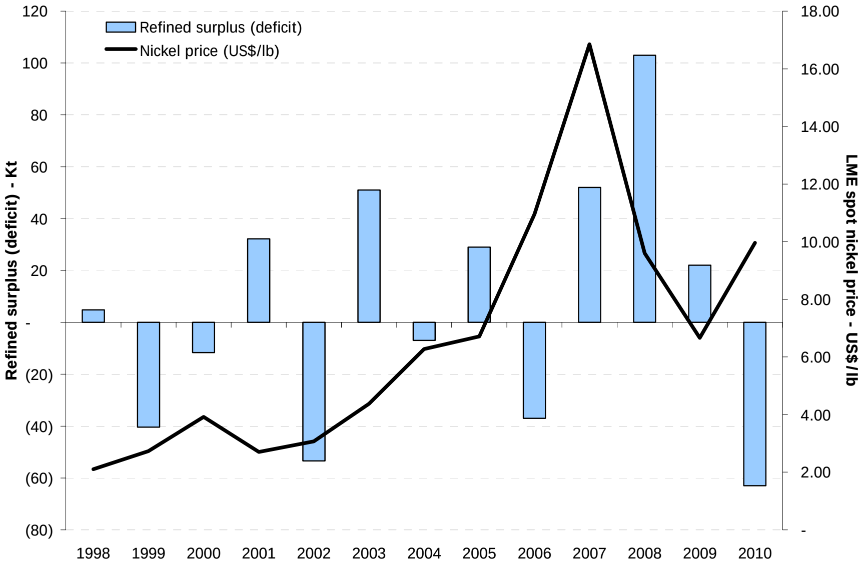
Exhibit 35: Nickel Pig Iron Past and Future Production



Source: Brook Hunt, Credit Suisse estimates.

Nickel prices rallied in the beginning of 2010, achieving a peak of $12.50/lb. Concern about the debt crisis in Greece and other countries in the Euro zone resulted in decreases in nickel prices, which hit a low of US$8.14/lb in June 2010. The resolution of the strike at Sudbury sustained those low prices until improvement in stainless steel demand coupled with production constraints in the Chinese nickel pig iron industry pushed prices back up to US$10.60/lb in September 2010. Volatility has continued into early December 2010, and with a deficit expected in 2011, the volatility is likely to continue and perpetuate if projects that are expected in 2011 are delayed.

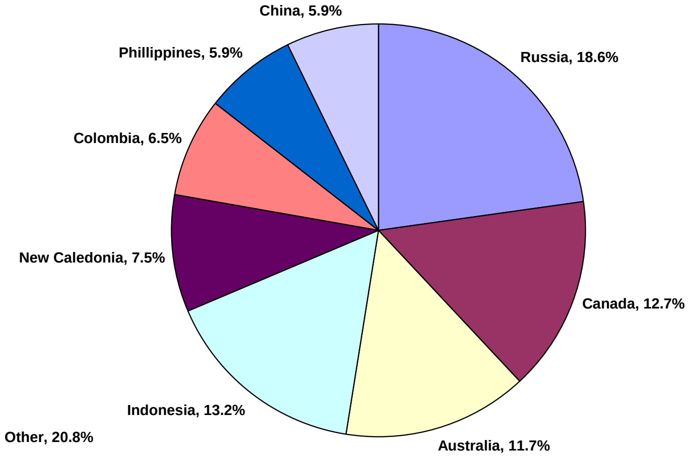
Exhibit 36: Global Metal Balance and LME Spot Nickel Price



Source: Brook Hunt, Credit Suisse estimates.

In the near term, growth in nickel supply of 6-7% per year will be supported by large projects due to start up by the end of 2011. Global nickel output is forecast to increase to 2.02Mt by 2015.

Exhibit 37: Nickel Mine Production by Region



Source: Brook Hunt.

Russia is currently the world's largest producer of nickel at 18.6%, followed by Canada (12.7%) and Australia (11.7%). Together, these three countries account for almost one-half of the total global production of nickel.

Exhibit 38: World Nickel Reserves by Country (in 000s tonnes)

Reserves (000s tonnes)	Reserves	% of Total	Production	% of Total
Russia	6,600	9.4%	266	18.6%
Canada	4,100	5.8%	181	12.7%
Australia	26,000	36.8%	167	11.7%
Indonesia	3,200	4.5%	189	13.2%
New Caledonia	7,100	10.1%	107	7.5%
Colombia	1,700	2.4%	93	6.5%
Phillippines	940	1.3%	85	5.9%
China	1,100	1.6%	84	5.9%
Cuba	5,500	7.8%	65	4.5%
Brazil	4,500	6.4%	57	4.0%
Dominican Republic	840	1.2%	0	0.0%
South Africa	3,700	5.2%	34	2.4%
Other	3,800	5.4%	28	2.0%
Botswana	490	0.7%	36	2.5%
Greece	490	0.7%	14	1.0%
Venezuela	490	0.7%	12	0.8%
Zimbabwe	15	0.0%	12	0.8%
World Total	**70,565**	**100.0%**	**1430**	**100.0%**

Source: USGS.

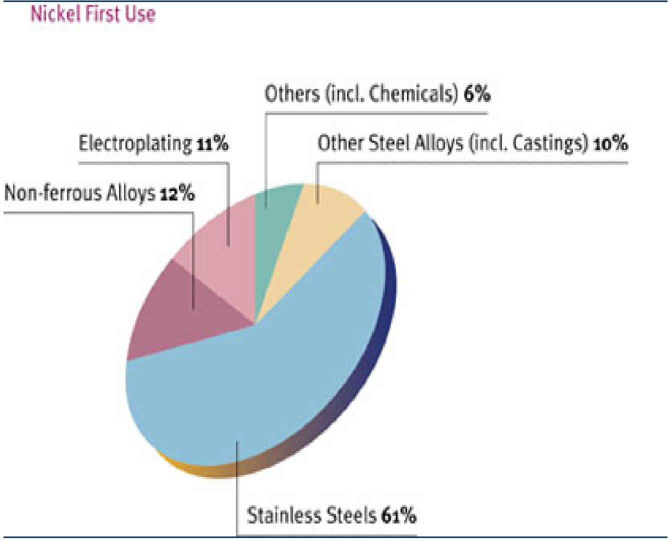
Reserves refer to material that is economically viable at the time of determination, December 31, 2009.

Australia has the world's largest economic reserves of Nickel at 36.8%, followed by New Caledonia (10.1%) and Russia (9.4%).

End Markets and Major Consuming Regions

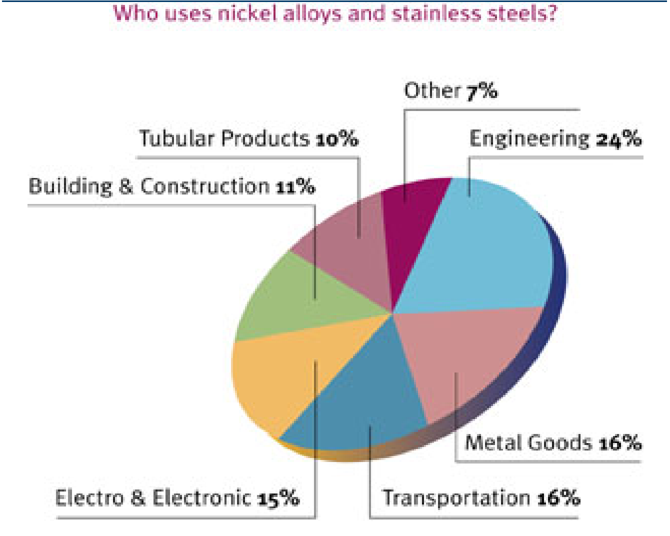
Nickel's prospects are closely tied to the stainless steel industry, a market that accounts for roughly two-thirds of primary nickel consumption. Stainless steel demand is largely driven by industrial production, with the major market being commercial aircraft, motor vehicle, and consumer durables production. In 2010, global stainless steel production is estimated at 30.4 million tonnes, up around 21% from 2009. This puts global nickel consumption at 1.48 million tonnes, up 12% from 2009.

Exhibit 39: Global Nickel Consumption by First Use



Source: http://nickelinstitute.com.

Exhibit 40: Nickel Applications



Source: http://nickelinstitute.com.

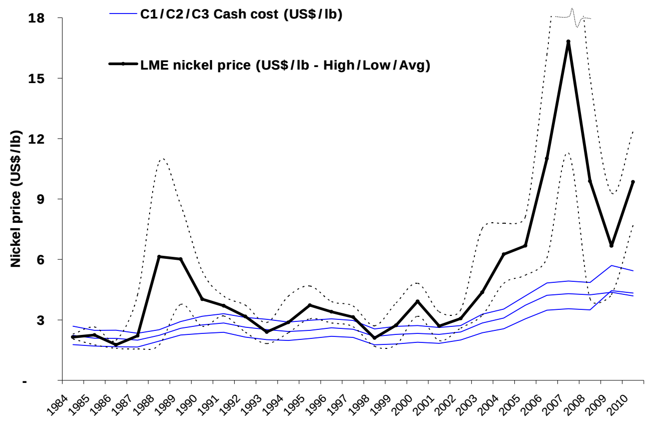
Stainless steel market will likely pick up in early 2011 as end users look to stock ahead in the early months of 2011.

Near-term growth in world nickel consumption is forecast to be 5% per year, to 1.9Mt by 2015 The world market is expected to improve gradually, supported by growth in the Chinese stainless steel industry, which will more than offset the maturing economies. The growth will be mostly driven by growth of 9% per year in China, where nickel consumption will increase to 730kt, equivalent to around 40% of the world total.

We have analyzed historical cash cost data provided by Brook Hunt for the past 25 years (1984-2010) and have compared the historical relationship between LME spot nickel prices and C1-C3 producer cash costs. As a result, we have estimated that in four previous periods (1988, 1993, 1998, and 2001), the spot nickel price traded as low as 10% below the 50th percentile of C1 cash costs.

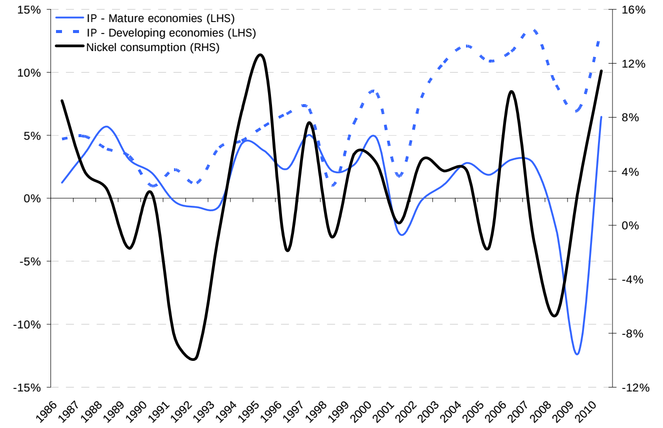
Spot nickel prices have traded as low as 10% below the 50th percentile of C1 cash costs

Exhibit 41: Nickel Cash Cost and LME Nickel Price



Source: Brook Hunt, Credit Suisse estimates.

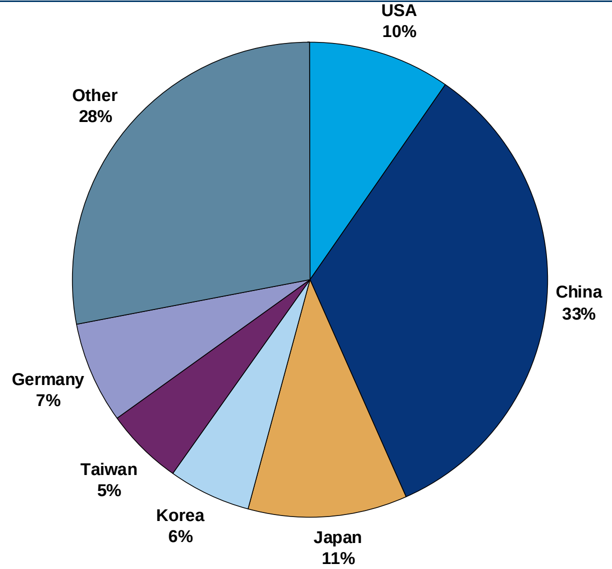
Exhibit 42: Industrial Production and Nickel Demand



Source: Brook Hunt, Credit Suisse estimates.

The increasing importance of China as the world's largest and fastest growing consumer of stainless steel continues to be the driver of nickel market growth. China current consumption of nickel is 33% of the total market, followed next by Japan (11%) and the United States (10%). Demand in stainless steel is driven by economic growth, relocation of industrial and manufacturing facilities, and strong levels of residential and commercial construction.

Exhibit 43: **Major Consuming Regions**



Source: Brook Hunt, Credit Suisse estimates.

Silicon Metal

Silicon metal (Si) is the 14th element of the periodic table and the second most common element in the earth's crust after oxygen. It is typically found naturally occurring in the form of silicon dioxide or silicates in combination with oxygen, most commonly in feldspar and quartz. Silicon metal is produced through the reaction of silica (silicon dioxide or SiO2), wood, charcoal, and coal in an electric arc furnace using carbon electrodes at over 1,900 degrees Celsius. The resultant liquid metal is typically 98% pure, which can then be refined to purities ranging from 50%, 99.999% (5-9s) and up to 99.99999999999% (11-9s) of purity.

Periodic table symbol: Si

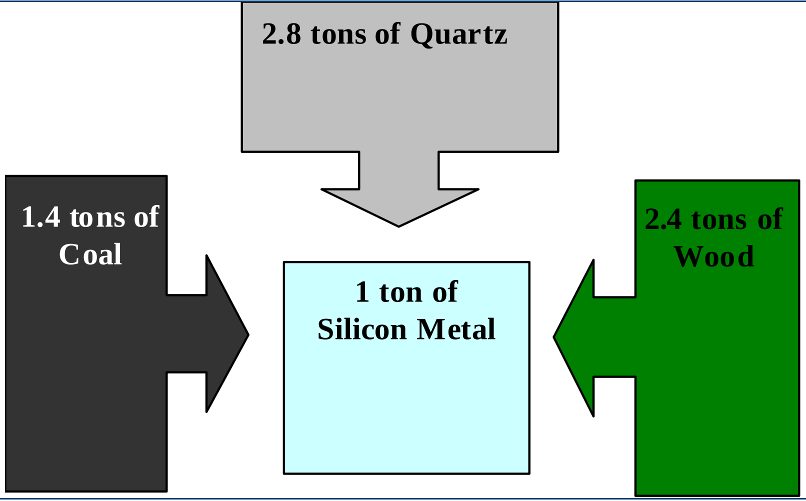
Atomic number: 14

Given silicon's abundance, strengthening, and conductivity characteristics and permeability, there are few substitutes for silicon in the majority of its applications.

Primary Production Process

The primary components to produce silicon metal include quartz, coal, wood chips, and electricity, as shown in Exhibit 44.

Exhibit 44: Key Raw Materials to Produce Silicon Metal



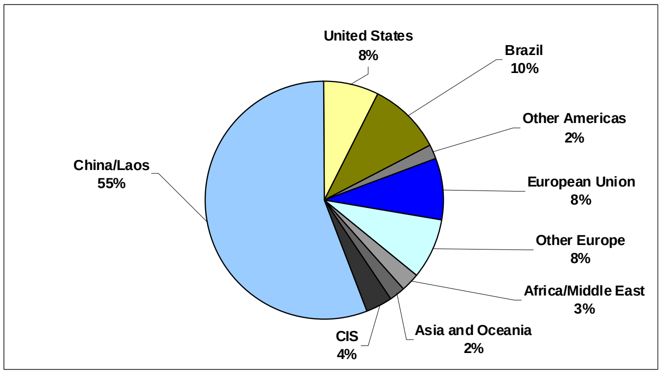
Source: Company data.

The quartz is mixed with the carbon agents (i.e., coal, coke, or wood chips) and then heated in an electric arc furnace using carbon electrodes to conduct the electric current and separate the liquid silicon from the oxygen, where it then falls to the bottom of the furnace and is extracted (i.e., tapped). In other words, the production process is essentially a smelting operation similar in nature to the aluminum production process.

Silicon Metal Supply

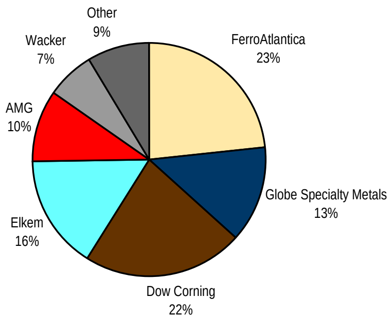
The silicon metal market is a tale of two markets: China versus the Western world. The global supply of silicon is dominated by China, which produces more than 50% of the world's silicon metal supply (versus 38% of global supply in 2003). Chinese supply is expected to continue to increase and will be the primary area for supply growth over the next five years, driven by growth in demand for silicon metal within China and the rest of the emerging markets from the rapid increase in polysilicon capacity, automotive manufacturing, and chemicals demand. Other major producers globally include Brazil, Norway, the United States, and France.

Exhibit 45: **Global Silicon Metal Production (by Country)**



Source: CRU, Company data, Credit Suisse estimates.

Exhibit 46: **Top Western World Silicon Metal Producers (2010)**



Source: CRU, Company data, Credit Suisse estimates.

As Exhibit 46 points out, the top six producers in the Western world control over 91% of Western world production, with almost 30% of Western world production actually comprising captive capacity not sold to third parties.

Unlike other metals such as aluminum, where China essentially consumes all of its produced metal, China only consumes roughly 25% of the world's supply of silicon metal, leaving it vastly oversupplied by roughly 450kt. As a response, there are significant import tariffs currently in place in the United States, the European Union, Australia, and Japan on Chinese material aimed at limiting the extent of Chinese material imported into the local markets.

Exhibit 47: **Summary of Major Regional Silicon Metal Tariffs in Place**

Tariff Country/Region	Source Country	Tariff Rate	Upcoming Sunset Review Period
USA	China	139.5%	Nov-11
USA	Russia	79.4%	Jul-13
European Union	China	49.0%	
Australia	China	8.1%	

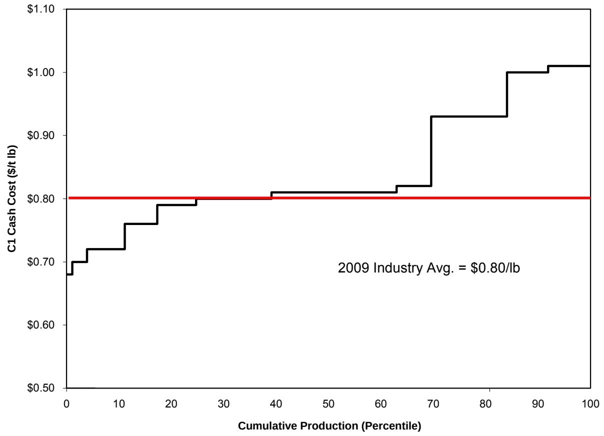
Source: USGS, ITC, Credit Suisse estimates.

Global Cost Curve

As of 2009, industry estimates point to a median cash cost for Western World production of roughly $0.80/lb. Industry estimates are that China's cash costs are significantly lower, given the country's significant quartz reserves.

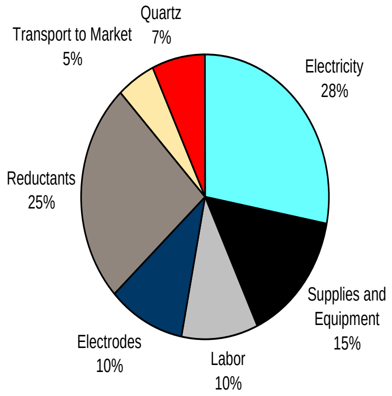
Generally speaking, energy comprises roughly one-third of production costs; another 35-40% of costs are related to raw material inputs, 10% labor, with the remaining 10-15% comprising other factors.

Exhibit 48: Silicon Metal Western World Cost Curve, 2009 (Percentile)



Source: CRU, Company data, Credit Suisse estimates.

Exhibit 49: Silicon Metal Smelting Costs (Industry Average)



Source: CRU, Company data, Credit Suisse estimates.

Demand and End Markets

On the demand side, silicon metal's key end markets include chemicals, aluminum, solar, and steel.

End Markets

Silicon metal has three primary end markets, including the chemicals industry (roughly 40-50% of demand), the aluminum industry (roughly 40% of demand), and the solar/electrical industry (roughly 10-20% of demand).

Chemicals Industry

Silicon metal is used in the production of silicones, whose primary uses are as a bonding agent and a waterproofing agent in a variety of products, given its impermeability to water, flexibility, durability, and sustenance.

Key applications include cosmetics, adhesives, sealants, and paint, just to name a few, although the reality is that each of the major producers of silicones continue to develop new applications on a regular basis, providing continued organic demand growth, as well as regional emerging market growth owing to increasing wage growth.

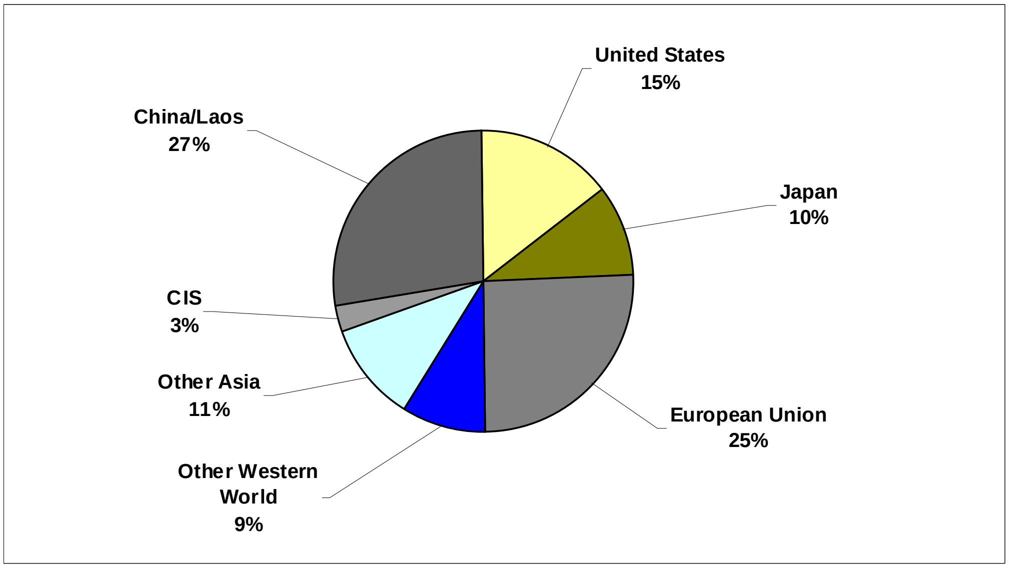
Aluminum Industry

The consumption of metallurgical-grade silicon for the aluminum industry in producing alloys and cast parts is actually the largest application of silicon metal globally (roughly 55% of industry demand). The silicon used by the aluminum industry is primarily tied to the automotive sector for the casting of alloy wheels and engines (roughly 80% of the silicon metal used in aluminum), given silicon's enhancement to strength, improvement in castability, reduction of cracking and shrinkage, high conductivity, and resistance to corrosion.

Solar/Electronics Industry

The solar/electronics industry accounts for 10-20% of demand and includes solar energy as well as semiconductor chips. Silicon is an invaluable input for the production of semiconductor wafers used in the production of semiconductor chips used in computers, transistors, mobile phones, radios, etc.. The primary growth segment for silicon metal in the long term is the photovoltaic applications for silicon, primarily in the production of polysilicon cells used in solar cell technology.

Exhibit 50: **Global Silicon Metal Demand (by Country)**



Source: CRU, Credit Suisse estimates.

Zinc

Periodic table symbol: Zn

Atomic number: 30

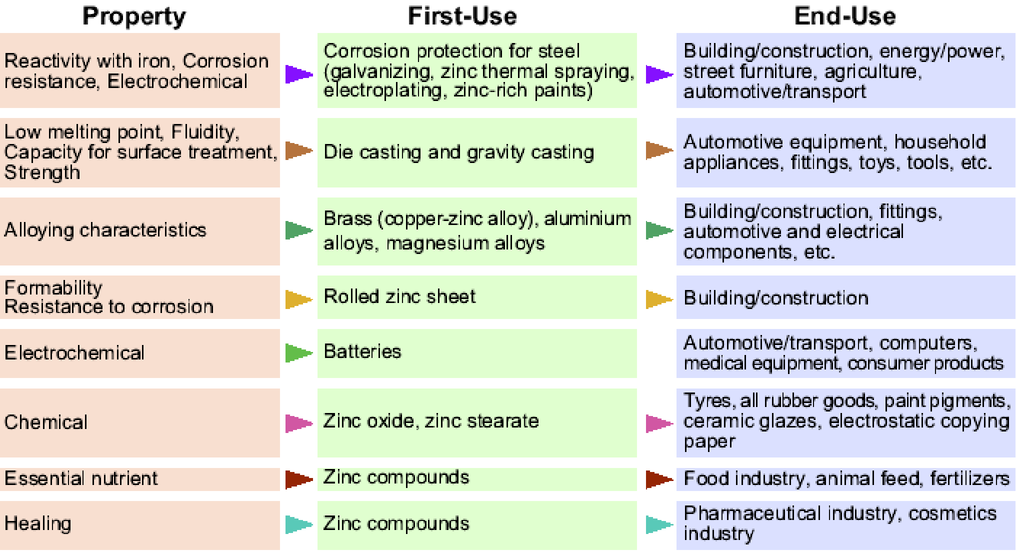
Zinc is one of the primary metals that form a part of not only the earth's crust, but also the atmosphere and the water bodies, and is the 27th most abundant element in the crust. Zinc is also an important part of the daily intake of all human beings and is necessary for the adequate functioning of the immune system. Zinc can be recycled indefinitely without loss in its properties, which renders it one of the most useful metals in industrial applications.

Properties and Uses of Zinc

Zinc is a metal that has diverse properties, such as low melting point, fluidity, corrosion resistance, and ductility, as well as electrochemical and chemical properties enabling its use in a variety of industrial applications. Exhibit 51 identifies the specific properties and the uses associated with zinc.

Zinc has traditionally been used in fertilizers, for industrial and commercial construction, and for protecting and improving the durability and corrosion resistance of steel. It is now also being used in batteries, water purification systems, satellite shields, varistors (used to protect appliances against power surges), and undersea cables (for remote operation of offshore oil wells).

Exhibit 51: **Zinc Properties and End Uses**



Property	First-Use	End-Use
Reactivity with iron, Corrosion resistance, Electrochemical	Corrosion protection for steel (galvanizing, zinc thermal spraying, electroplating, zinc-rich paints)	Building/construction, energy/power, street furniture, agriculture, automotive/transport
Low melting point, Fluidity, Capacity for surface treatment, Strength	Die casting and gravity casting	Automotive equipment, household appliances, fittings, toys, tools, etc.
Alloying characteristics	Brass (copper-zinc alloy), aluminium alloys, magnesium alloys	Building/construction, fittings, automotive and electrical components, etc.
Formability Resistance to corrosion	Rolled zinc sheet	Building/construction
Electrochemical	Batteries	Automotive/transport, computers, medical equipment, consumer products
Chemical	Zinc oxide, zinc stearate	Tyres, all rubber goods, paint pigments, ceramic glazes, electrostatic copying paper
Essential nutrient	Zinc compounds	Food industry, animal feed, fertilizers
Healing	Zinc compounds	Pharmaceutical industry, cosmetics industry

Source: International Zinc Association.

Zinc is most commonly used as a coating for iron and steel products, to make them resistant to rust and corrosion. The application of a zinc coating, known as galvanizing, is accomplished electrolytically or by hot-dip methods. Galvanizing accounts for about 57% of the worldwide use of zinc. The most commonly galvanized products are sheet and strip steel, tube and pipe, and wire and wire rope.

The automobile industry is a large user of galvanized steel and the second largest user of zinc globally. The desire to reduce weight and improve fuel efficiency has led to increased use of galvanized steel by the automotive industry to protect the thinner gauges of steel from corrosion. Both hot-dipped and electro-galvanized steel are used, as the thicker coating of hot-dipped steel gives more corrosion protection to unexposed surfaces and the thinner coating of electro-galvanized steel provides a smoother finish for exposed painted surfaces.

Galvanized sheet and strip steel is also widely used by the construction industry for roofing and siding and for heating and ventilation ducts, as well as for many other applications. Nails and other building materials are often hot-dip galvanized. Zinc and zinc-aluminum thermally sprayed coatings are used for the long-term corrosion protection of large steel structures, such as bridges and hydroelectric transmission towers. Another important use of zinc is in the production of a vast range of die-cast products. Because it has a relatively low melting point and is very fluid, zinc is easy to pour when melted. Therefore, it is well suited to rapid, assembly-line die-casting, particularly to produce small and intricate shapes.

In terms of sectors, construction accounts for nearly one-half the zinc demand, with consumer and electrical uses accounting for more than one-third. Although the bulk of demand growth has come in the form of zinc-coated steel, where demand has nearly doubled, zinc-based alloys and brass and bronze materials have also contributed to a spurt in demand over the past 20 years. Since zinc is used as an additive in the process of galvanizing and alloying, demand is largely driven by sectors using these end products. The following provides an overview of the sectoral end markets.

Construction. Construction is the largest market for zinc, accounting for 49% of total consumption. Zinc is used in production of galvanized steel, which is used in heating and air vent ducting, roofing, partitions, and floor systems. The Chinese infrastructure boom is a major driving force behind this sector.

Transport. Automotive manufacturers are keen on reducing the cost of vehicles while retaining the corrosion resistance of the materials; therefore, galvanized steel and zinc alloys are used.

Consumer and industrial usage. Consumer goods, such as refrigerators, computers, etc., use zinc-coated steel and thus contribute to overall zinc demand. However, this is only a small part of the picture. The real demand in this category comes from industrial equipment and machinery manufacturers using zinc-coated steel and zinc alloys for a variety of applications ranging from large tanks and extractor ducting and fans to nuts and bolts.

Primary Production Process

Zinc Mining

About 80% of zinc mines are underground, 8% are of the open pit type, and the remainder are a combination of both. In terms of production volume, however, open pit mines account for approximately 15% and underground mines about 65%, with the remainder coming from combined underground and open pit mining operations.

Rarely is the ore, as mined, rich enough to be used directly by smelters; it needs to be concentrated. Zinc ores generally contain 5-15% zinc. To concentrate the ore, it is first crushed and then ground to enable optimal separation from the other minerals. Typically, a zinc concentrate contains 50-55% of zinc, with some copper, lead, silver, and/or gold. Zinc concentration is usually done at the mine site to keep transport costs to smelters as low as possible.

More than 95% of the world's zinc is produced from zinc blend (ZnS). Apart from zinc, the concentrate contains approximately 25-30% or more of sulfur, as well as different amounts of iron, copper, lead, silver, and other minerals. Before metallic zinc can be recovered by using either hydrometallurgical or pyrometallurgical techniques, sulfur in the concentrate must be removed. This is done by roasting or sintering. The concentrate is brought to a temperature of more than 900°C where zinc sulfide (ZnS) converts into the more active zinc oxide (ZnO). At the same time, sulfur reacts with oxygen, releasing sulfur dioxide, which subsequently is converted to sulfuric acid, an important commercial byproduct.

The Hydrometallurgical Process

In a leaching stage, the zinc oxide is separated from the other calcines with the use of sulfuric acid. The zinc content dissolves, whereas iron precipitates and lead and silver remain undissolved. However, the dissolved solution contains some impurities that need to be eliminated in order to obtain a high-purity zinc product at the end of the production process. Purification is mainly done by adding zinc dust to the solution. As all the elements to be removed lie below zinc in the electrochemical series, they can be precipitated by cementation.

The obtained purified solution passes an electrolytic process in which the purified solution is electrolyzed between lead alloy anodes and aluminum cathodes. An electrical current is circulated through the electrolyte by applying an electrical difference of 3.3-3.5 volts between the anode and cathode, causing the zinc to deposit on the aluminum cathodes in high purity. The deposited zinc is stripped off, dried, melted, and cast into ingots. The zinc ingots may have different grades: high grade (HG, 99.95% of zinc), and special high grade (SHG, 99.99%). More than 90% of refined zinc currently is produced by the hydrometallurgical process in electrolytic plants.

The Pyrometallurgical Process

The Imperial Smelting (IS) process has been the most important pyrometallurgical process. It allows simultaneous production of zinc and lead metals, roughly one ton of lead for every two tons of zinc. It is particularly indicated for treating concentrates with a significant amount of lead. The Imperial Smelting process is based on the reduction of zinc and lead into metal with carbon in a specially designed Imperial Smelting furnace.

Preheated air is blown from below in the shaft furnace. The sinter is charged together with the preheated coke at the top of the furnace. Temperatures range from 1,000°C at the top to 1,500°C or more in the center of the furnace. The coke is converted into carbon monoxide, which provides the means to reduce zinc and lead oxides to metallic zinc and lead. The lead that is below its boiling point flows from the bottom of the blast furnace, carrying copper, silver, and gold with it. Zinc evaporates and passes out of the furnace near the top along with other gases. To avoid oxidizing back to zinc oxide, the zinc vapor is rapidly quenched and dissolved in a spray of molten lead in a condenser (lead splash condenser). By cooling the lead, crude zinc is released and is separated. The lead returns to the condensing process for another cycle of dissolving and then releasing more zinc.

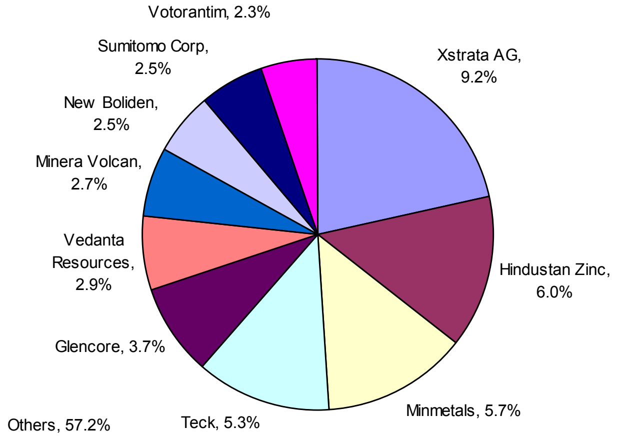
The IS process is an energy-intensive process and thus became very expensive following the rise of energy prices in recent years. Along with the lower production of bulk concentrates containing significant amounts of lead, this gradually led to abandoning the Imperial Smelting process. Imperial Smelting furnaces currently are in operation only in Japan, China, and Poland.

The major difference of the hydrometallurgical process and the Imperial Smelting process is that the first produces very pure zinc directly, whereas the latter produces lower-grade zinc that still contains significant impurities that have to be removed by thermal refining in the zinc refinery.

Global Mine Supply

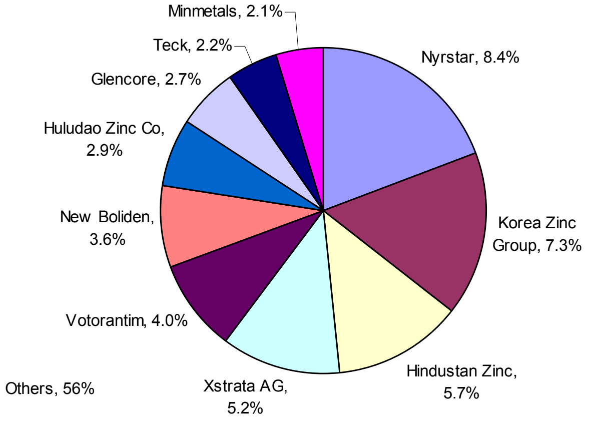
The top ten producers share about 43% of the mine production (40% in 2008) and some 44% of refined zinc output (45% in 2008). The increasing concentration of production by miners should result in higher pricing power and better control over supply-side economics. However, given that the two main participants in the supply chain (miners and smelters) often operate independently, coupled with the shortage of concentrate storage capacity, miners will generally have an upper hand, and the treatment charges will be regulated more by the demand for concentrate than by the price of the metal.

Exhibit 52: Top Ten Mine Zinc Producers



Source: Brook Hunt, Credit Suisse estimates.

Exhibit 53: Top Ten Refined Zinc Producers



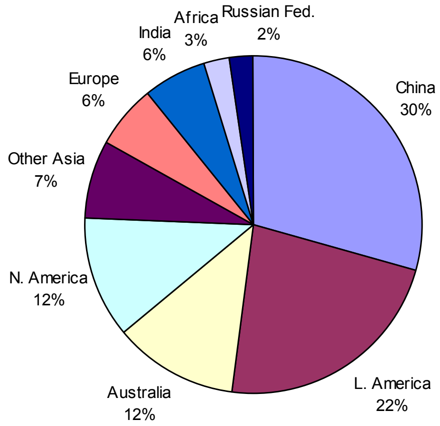
Source: Brook Hunt, Credit Suisse estimates.

Xstrata remains the world's largest mined zinc miner (1.1 Mln tonnes of estimated zinc in concentrate in 2010), with Hindustan Zinc in second place (730,000 tonnes of estimated zinc in concentrate). In 2010, we estimate global mine production of zinc to total 12 Mln tonnes.

Nyrstar remains the world's largest refined zinc producer (1.1 Mln tonnes of estimated refined zinc production in 2010) followed by Korea Zinc Group (949,000 tonnes of estimated refined zinc production in 2010). Hindustan Zinc has surpassed Xstrata AG to become the third largest refined zinc producer (736,000 tonnes of estimated refined zinc production in 2010).

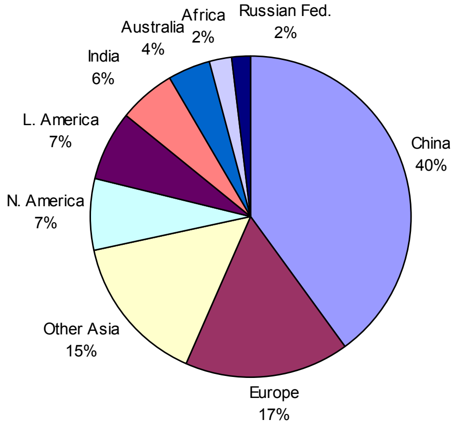
Exhibit 54 and Exhibit 55 depict production of mined zinc production and refined zinc capacity by region.

Exhibit 54: Global Zinc Mine Production by Region



Source: Brook Hunt, Credit Suisse estimates.

Exhibit 55: Global Refined Zinc Capacity by Region



Source: Brook Hunt, Credit Suisse estimates.

China is currently the world's largest producer of mined zinc at 30%, followed by Latin America (22%) and Australia (12%). Together, these three regions account for 64% of global production of zinc. Likewise, China accounts for 40% of refined zinc capacity globally, with the European market a distant second at 17%.

Exhibit 56: **World Zinc Reserves by Country**

Country	Reserves (k tonnes)	% of Total
China	33,000	17%
Australia	21,000	11%
Peru	19,000	10%
Kazakhstan	17,000	9%
United States	14,000	7%
Mexico	14,000	7%
India	10,000	5%
Canada	8,000	4%
Ireland	2,000	1%
Other countries	62,000	31%
World Total	**200,000**	**100%**

Source: USGS.

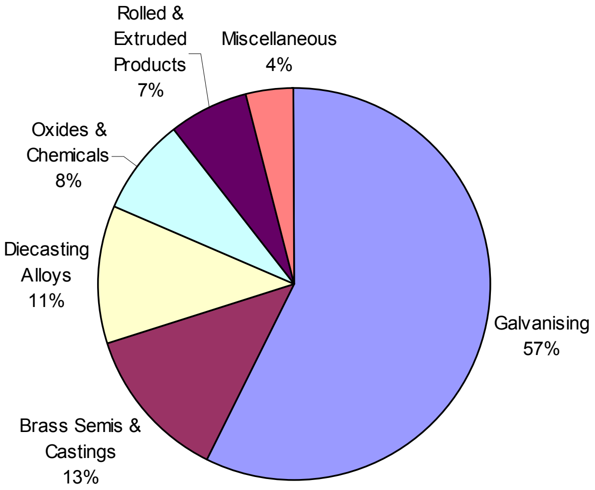
**Reserves refer to material that is economically viable at the time of determination; January 2010.*

Combined, China (17%), Australia (11%), and Peru (10%) hold more than one-third of the world's zinc reserves.

Global Demand

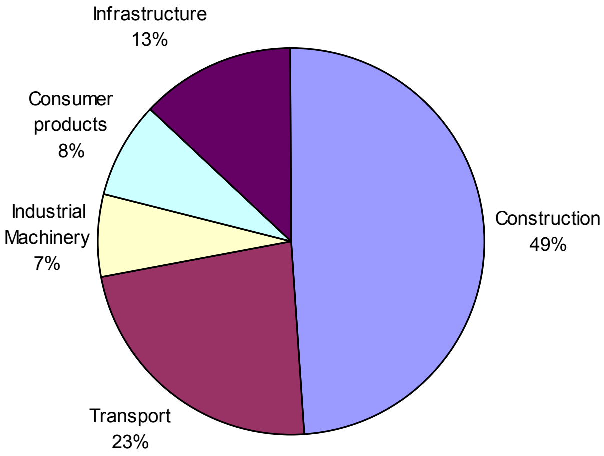
Demand for zinc is a derived demand, dependent on the usage of end products such as galvanized steel, industrial machinery, and consumer goods. Exhibit 57 and Exhibit 58 illustrate first and end uses of zinc. Construction and transportation are the largest end-use sectors for zinc, and together account for 72% of the estimated global end-use zinc consumption in 2010. Infrastructure and consumer products constitute 13% and 8% of end use, respectively. Most zinc is used in galvanizing, which accounts for 57% of estimated global consumption by first use.

Exhibit 57: **Global Zinc Consumption by First Use**



Source: Brook Hunt, Credit Suisse estimates.

Exhibit 58: **Global Zinc Consumption by End Use**

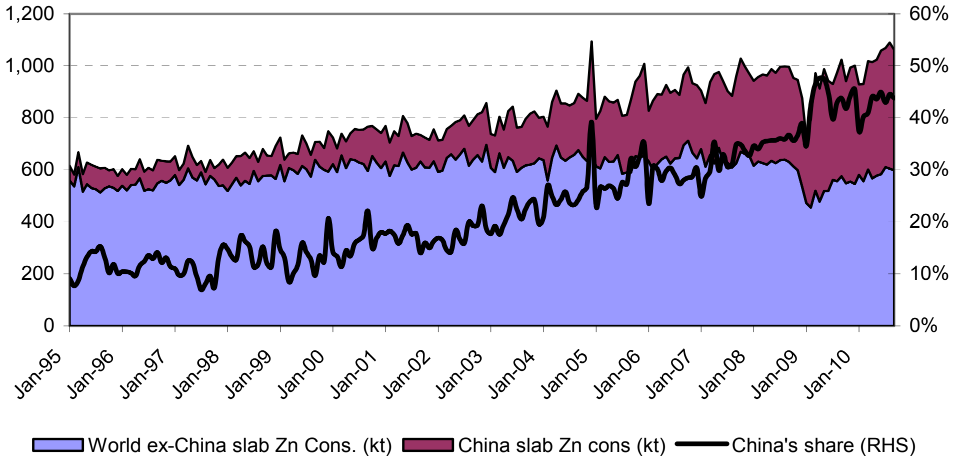


Source: Brook Hunt, Credit Suisse estimates.

End Markets and Major Consuming Regions

Global consumption continues to be driven by China, which accounts for 41% (Exhibit 59) of the estimated zinc demand in 2010, up from 34% in 2008. China's gain in market demand has come at the expense of the developed regions, such as North America and Western Europe, where demand has fallen by 18% and 16%, respectively, over the past two years. China's zinc consumption is driven by infrastructure development and automotive production. Even though the growth in automobile output in China has been decelerating through 2010, consumption of zinc has recovered, driven by the construction and the consumer durable sector.

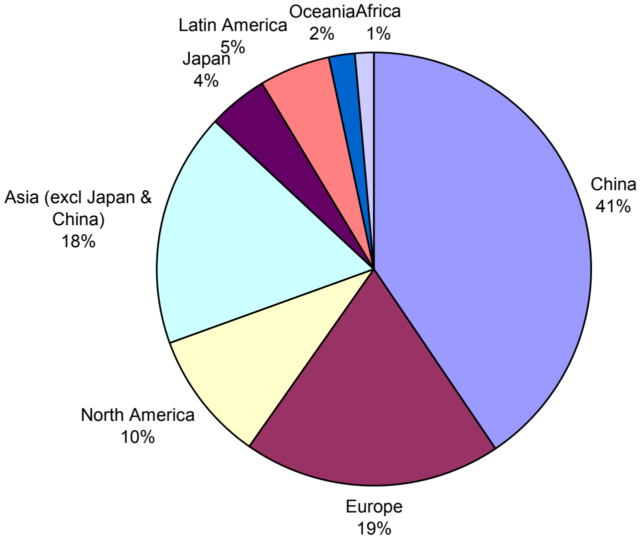
Exhibit 59: **China's Share of Consumption Continues to Climb.**



Source: WBMS, Credit Suisse estimates.

In 2010, we estimate global zinc consumption rebounded by 9% to 11.6 Mt, from the weak demand exhibited in 2009, mainly led by China, India, and other developing economies such as Brazil, coincident with strong economic development. In the mature economies, consumption in some mature economies, such as Western Europe, has recovered, although in others, such as the United States, we expect 2011 to be the first year consumption growth will resume.

Exhibit 60: **Zinc Consumption by Region, 2010E**

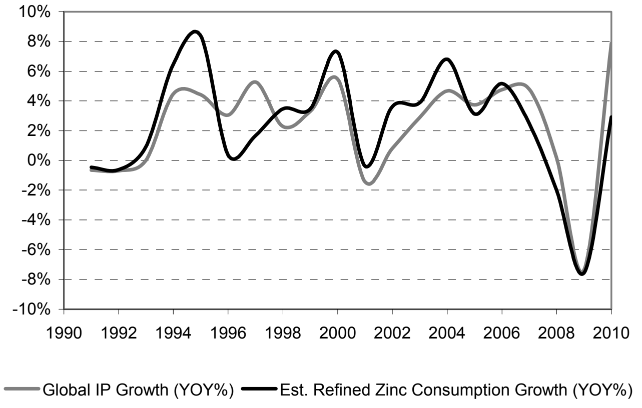


Source: Brook Hunt, Credit Suisse estimates.

Zinc Demand and Industrial Production

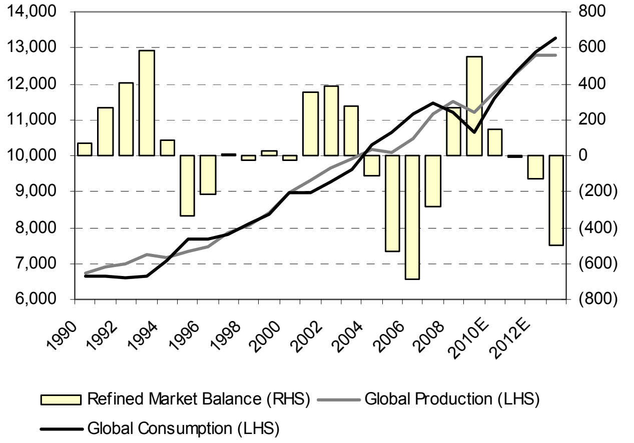
As demand for zinc is a derived demand, growth in its use is significantly driven by growth in global industrial production. We have compared the change in industrial production with the corresponding change in zinc consumption. Exhibit 61 illustrates that growth in zinc demand is largely dominated by industrial production growth.

Exhibit 61: Zinc Demand and Global IP Growth



Source: Brook Hunt, Credit Suisse estimates.

Exhibit 62: Zinc Global Supply/Demand Balance

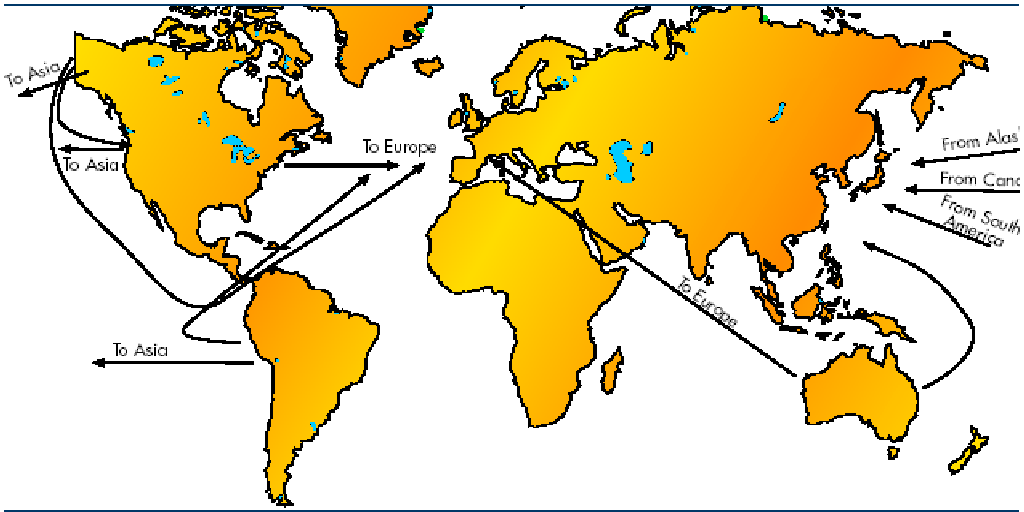


Source: Brook Hunt, Credit Suisse estimates.

Global Trade in Zinc

The trade flow diagram in Exhibit 63 shows the trade flow of zinc concentrate, mainly from the surplus regions of Australia and the Americas to the deficit European and Asian regions.

Exhibit 63: Global Trade Flow of Zinc Concentrate



Source: ILZSG.

Precious Metals

- **Gold**
- **Platinum Group Metals**
- **Silver**

Gold

Periodic table symbol: AU

Atomic number: 79

Gold, from the Indo-European word for yellow, is one of the rarest and oldest metals in the world. The earliest recorded mining date was by ancient Egyptians in about 2000 BC, followed by Peruvian artisans in 1200 BC. However, gold reached new heights during the Roman Empire. Since then, gold's appearance and scarcity has made it popular in art, jewelry, and architecture, while its metallurgical properties have made it useful in electronics (wiring, semiconductors, etc.) and dentistry. Gold is also widely viewed as an investment vehicle, used as a store of value by central banks and investors. Gold-based exchange traded funds (ETFs) are also backed by physical gold.

Gold is the end product after several chemical and mechanical processes separate the ore and refine it to 99.99% purity, the standard for refinement.

Properties of Gold

Corrosion resistance. Gold is extremely nonreactive with oxygen, which lowers the risk of rust or tarnish. The tarnish that is often seen on gold surfaces is usually just a darkening of the reflective surface.

Hardness. Gold is a very soft metal. Thus, if used in industrial applications, it is often alloyed with a harder metal, such as silver or copper, to improve durability.

Conductivity. Gold is an excellent conductor of both heat and electricity (second only to copper and silver), as it is not affected by air and other reagents, making it ideal for electric wiring, although expensive relative to other metals (copper, silver, and aluminum).

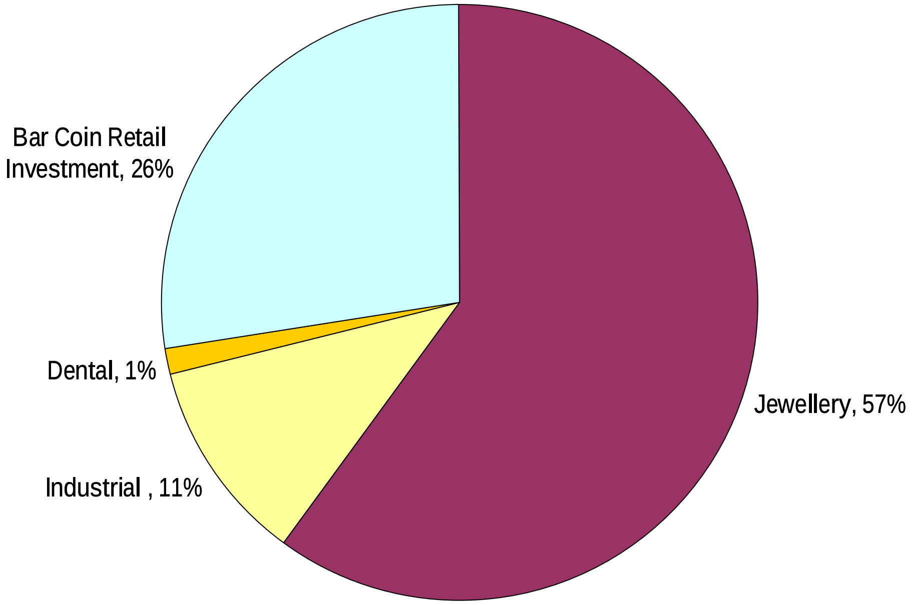
Ductile and malleable. Gold is an extremely malleable and ductile metal, making it ideal for wire and sheet products (i.e., gold wiring, plating, gold leaf, etc.).

Strong and recyclable. Pure gold is easily recyclable, as it can be melted (melting point of 1,064 degrees Celsius), rerefined, and recycled for new uses. Given gold's strength and durability (its properties make it virtually indestructible), virtually every ounce of gold ever mined remains in existence, with roughly 2% of this amount currently lost or unaccounted for.

Rare and valuable. Gold is one of the rarest metals on earth, thus its classification as a precious metal. It is estimated that there is approximately 90,000 tonnes of contained gold in the ground globally, with global annual production of roughly 2,500 tonnes as of 2005. To put this in perspective, only 155,000 tonnes of gold is estimated to have been mined throughout history (64% of this mined since 1950), with 2% of this lost or currently unaccounted for. Owing to gold's significant value per ounce, ore deposits with as little as 0.5 grams per ton of gold are still economically viable to develop and mine.

Uses of Gold

Exhibit 64: **2010 Global Gold Consumption, by End Market**



Source: World Gold Council. Data for 2010 up to end of Q3 2010.*

Luxury. Gold jewelry constitutes the bulk of demand for the yellow metal; gold can also be used in architectural applications, such as gold leaf being applied to ceilings or buildings. Gold is also used by artists in sculptures and other works. Jewelry demand been declining (-16% since 2005), while retail investment has been increasing (+10% since 2005), as investors increase gold weightings in their portfolios.

Investments. Gold is used as an alternative investment vehicle around the world and is considered a store of value during inflation. Gold bars, coins, and jewelry are all forms of investment and savings. Gold ETFs are also available and have been growing in popularity as an alternative to direct physical buying of gold. When stacked against central banks, ETFs collectively are currently the sixth largest holder of gold.

Electronics. Because gold is a noncorrosive metal, it is widely used to plate connectors used in electronics. Its conductivity and malleability also make it ideal in semiconductor applications, wiring, circuit boards, and nanotechnology

Medicine. Gold is used in tooth restoration, as in crowns and bridges. Certain cardiac devices also use gold.

Transportation. Similar to other metals, gold is utilized in automobile wiring owing to its conductivity and malleability, although the extent of its use is limited by its relatively high cost.

Types of Products

- *Pure gold*. Owing to its pureness and value, pure gold is most often used in jewelry, wiring, and architecture.
- *Gold alloys*. As gold is a very soft metal, gold alloy are more often used in applications that require strength and durability, including construction, dentistry, and some types of jewelry.

Substitutability

In jewelry applications, as well as for costume jewelry, platinum, white gold, palladium, and silver are common substitutes for gold. Aluminum or copper wiring can also be used in place of gold wiring in most electrical applications.

Primary Production Process

Gold is mined via either open pit or underground mines, depending on the geology and geography of the ore deposit and the surrounding area. Deposits are typically either lode deposits (deposits found fissures in rocks), or placer deposits (gold that has settled to the bottom of a riverbed). Metals such as copper, zinc, and lead are also commonly found as byproducts within the ore bodies.

Open pit mining is typically lower cost than underground, given the nature of the operations, but grades are typically lower (less than three grams per ton). Underground mines are typically used to access gold veins (also known as lode deposits) that are deep below the earth's crust and typically found in long, thin trend formations in gold-rich regions. On average, these ore bodies tend to be higher-grade deposits versus deposits accessed via open pit mines. (For a more detailed description of the mining methods, refer to the copper section.)

Processing

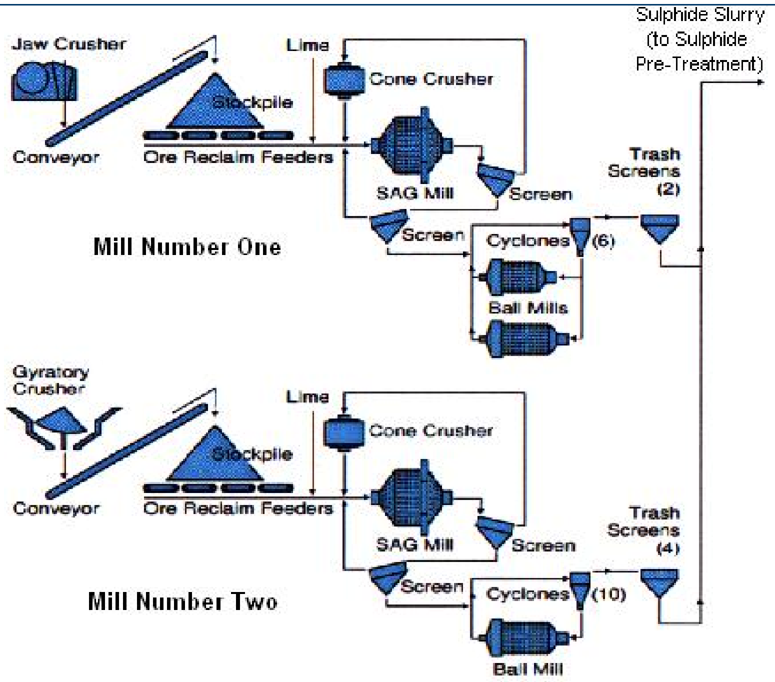
Once the ore is mined, it needs to be processed further. Before the ore is processed, it is first crushed and sorted in a mill according to composition to ensure the proper processing method is used to maximize gold recovery. Ores containing less gold (i.e., lower-grade ores) are typically sent straight to the leaching process without much preparation, while higher-grade ores are processed further to ensure optimum gold recovery. With higher gold prices, some very low-grade ores that are amenable to leaching are leached without first being crushed; these are called dump leach ores.

The three primary ore types are each prepared differently before entering the leaching phase of the process.

1. *Refractory ores* contain carbon and sulfide, which are removed by roasting the ores at a temperature of 1,000 degrees Fahrenheit before entering the leaching phase.
2. *Sulfide refractory ores* do not contain carbon, so the sulfides are removed by oxidizing the ore in an autoclave.
3. *Oxide ores* do not contain carbon or sulfides and therefore do not need any pretreatment and move straight into the leaching phase.

Sulfide Ore Processing

Exhibit 65: SAG Circuit Flow Chart



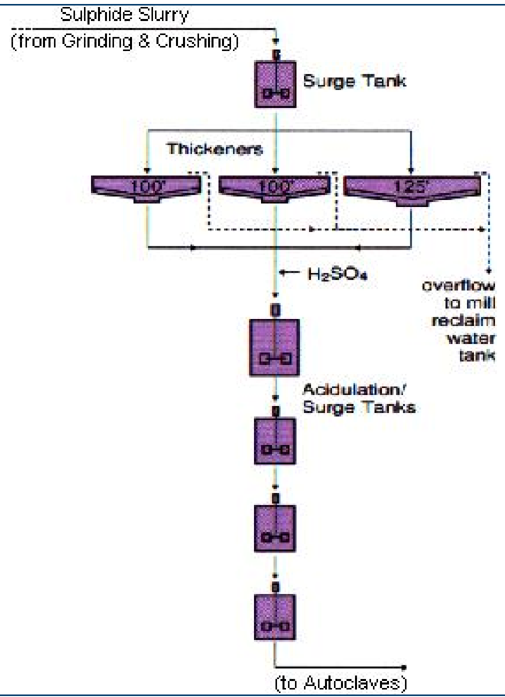
Source: MetSoc.

Step one: crushing and grinding. Two types of grinding circuits are used to crush the ore, depending on the geology that would optimize mill throughput: (1) semiautogenous grinding (SAG) mills and (2) autogenous mills.

- Semiautogenous grinding (SAG) mills crush and grind the ore using large steel balls.
- Autogenous mills use the harder ores to grind other ore; do not utilize steel balls.

Step two: acidulation. Once the ore has been crushed and mixed with water to create slurry, it proceeds to acidulation. The slurry is thickened, with excess water removed to improve the efficiency of the autoclaving process.

Exhibit 66: Acidulation Flow Chart

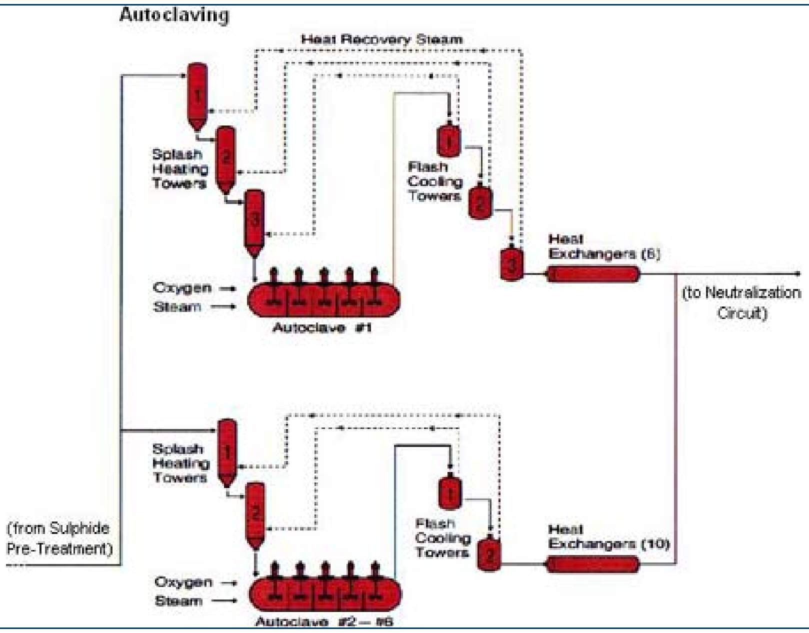


Source: MetSoc.

Step three: roasting or pressure oxidation autoclaving. Depending on the geology of the ore, the ore is then further processed through roasters or autoclaves.

- *Roasting.* Roasters heat the ore with air and oxygen to burn off the excess carbon and oxidize the sulfide minerals.
- *Autoclaving.* The ore is oxidized at high pressure and temperature (approximately 210 degrees Celsius) to improve the effectiveness of the leaching process. The ore then goes through a neutralization circuit before it is sent for leaching.

Exhibit 67: Autoclave Circuit Flow Chart



Source: MetSoc.

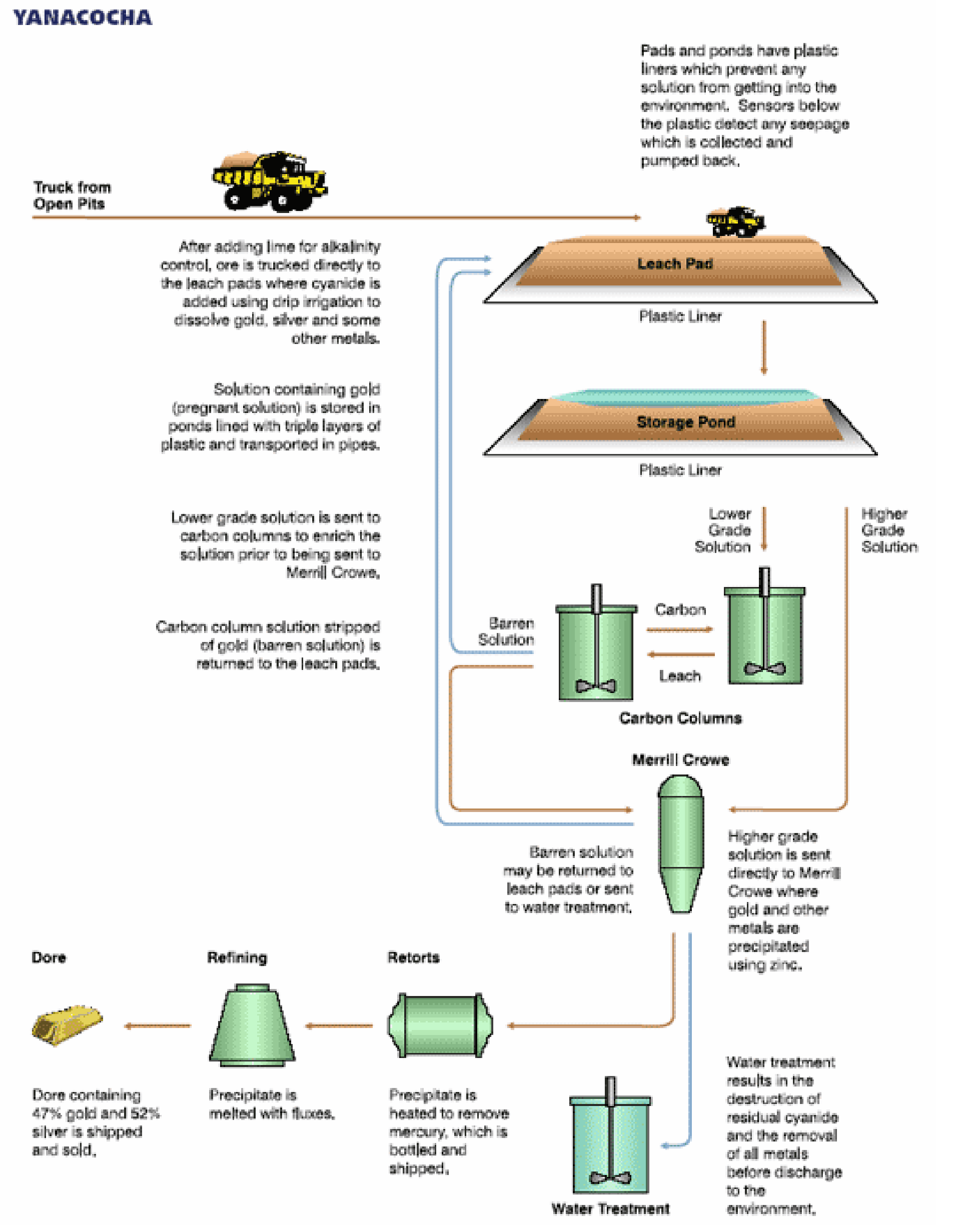
Step four: leaching. In the Carbon-in-Leach Process (CIL), sulfide ores that have been further processed are then sent for leaching. Leaching essentially involves the dissolution of the gold ore using a cyanide solution on leach pads. This acidic leaching proves to be most effective for oxide ores. The sulfide ores are typically first oxidized by bacterial leaching. The leaching process (especially bacterial leaching) can be extremely slow and may take months or even years if not modified. Using smaller crushed ore particles, more concentrated acid, higher temperature, and pressure are some of the methods typically used to accelerate the process. However, these modifications may significantly increase the cost of production.

Heap leaching. Oxide ores (typically lower grade) that are either run-of-mine, dump leach (unprocessed) or crushed are placed on impervious pads where a weak cyanide solution is applied to the top of the stack.

The gold then dissolves into a solution that is collected and then sent to a recovery plant (typically a Merrill-Crowe facility) where the gold is extracted.

Once the gold is extracted from the solution and chemically stripped, the gold is melted into dore bars (typically 90% gold), which are then shipped to a refinery for further processing.

Exhibit 68: Leaching Process Flow Chart


YANACOCHA
Pads and ponds have plastic liners which prevent any solution from getting into the environment. Sensors below the plastic detect any seepage which is collected and pumped back.
Truck from Open Pits
After adding lime for alkalinity control, ore is trucked directly to the leach pads where cyanide is added using drip irrigation to dissolve gold, silver and some other metals.
Leach Pad
Plastic Liner
Solution containing gold (pregnant solution) is stored in ponds lined with triple layers of plastic and transported in pipes.
Storage Pond
Plastic Liner
Lower grade solution is sent to carbon columns to enrich the solution prior to being sent to Merrill Crowe.
Lower Grade Solution
Higher Grade Solution
Carbon column solution stripped of gold (barren solution) is returned to the leach pads.
Barren Solution
Carbon
Leach
Carbon Columns
Merrill Crowe
Barren solution may be returned to leach pads or sent to water treatment.
Higher grade solution is sent directly to Merrill Crowe where gold and other metals are precipitated using zinc.
Dore
Refining
Retorts
Dore containing 47% gold and 52% silver is shipped and sold.
Precipitate is melted with fluxes.
Precipitate is heated to remove mercury, which is bottled and shipped.
Water treatment results in the destruction of residual cyanide and the removal of all metals before discharge to the environment.
Water Treatment

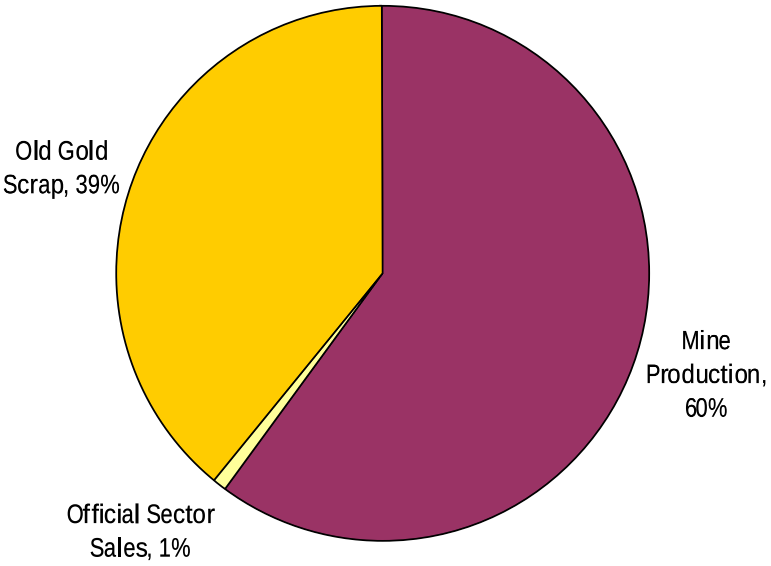
Source: Newmont Mining.

Refining Process

To purify the dore bars further, the bars are melted and treated with chloride, which separates the impurities, leaving gold that is 99.5% in purity. The mold is then cast into electrodes known as anodes. Electricity is then passed through the gold within an electrolytic cell, which results in the final purity of 99.99% pure gold.

Global Mine Supply

Exhibit 69: Breakdown of Physical Gold Supply (2009)

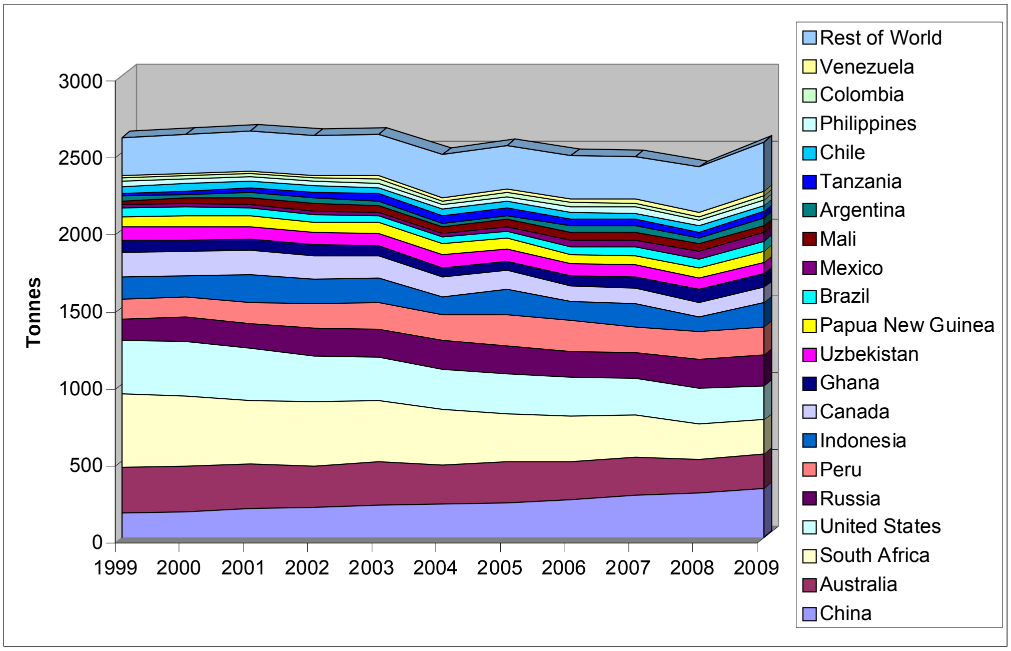


Source: GFMS 2009.

Mine production accounts for 60% of the world's gold supply and has remained at these levels consistently over time. Recycled gold makes up 39% of total supply, which is a 14% increase over the past two years and is largely the result of gold rising to all-time highs. Official Sector Sales, also referred to as Central Bank Sales, have decreased approximately 89% in the past three years to a mere 41 tonnes in 2009, representing 1% of annual gold supply, from 370 tonnes in 2006.. Central banks are continuing to become net buyers of gold, as the governments seek a hedge against global currency destabilization and inflation concerns. It may become more common for Official Sector Sales to be negative rather than positive.

Mine Production

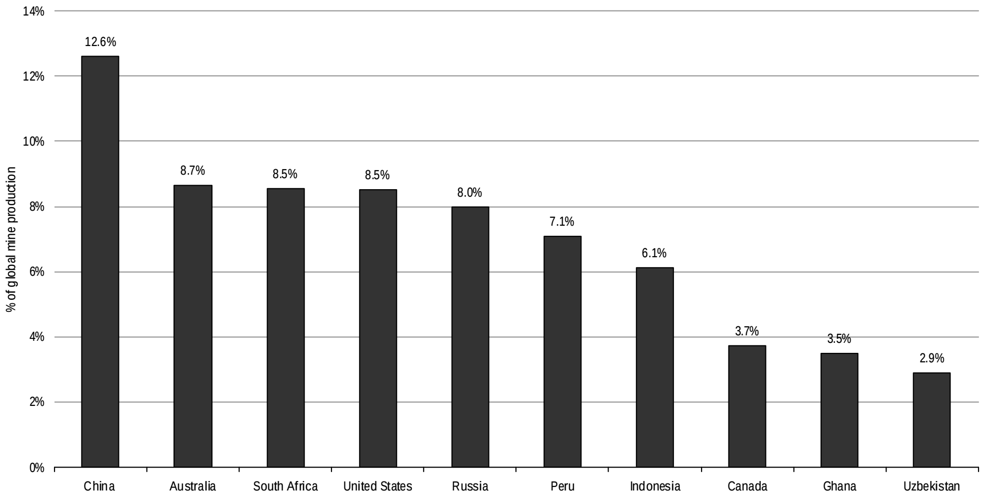
Exhibit 70: Trends in Global Mine Supply (by Country)



Source: GFMS.

Over the past nine years, total global mine production has been decreasing at an average rate of 1% per year, with 2009 showing the beginnings of a supply-side reversal, with an approximate 7% increase. This incremental increase is expected, as gold prices have risen, bringing on new production from previously uneconomical projects. It is also of interest to point out those countries that have been longstanding leaders in gold production but have since experienced long-term secular declines. South Africa, once the stand-alone leader in global gold production, has lost its position to China, which has been growing production at 8% per annum for the past five years.

Exhibit 71: Top 10 Gold-Producing Countries in 2009



Source: GFMS 2010.

Overall, gold production is increasingly spread out among various countries and geographic regions, as newer deposits are developed in new mining regions. With the largest single producer representing only 12.6% of global gold production and deposits at existing mines around the world continuing to decline in ore grades, no one region looks to dominate (which we would quantify as over 25% of world production) gold production in a material manner within the next decade.

Exhibit 72: 2009 World Gold Reserves by Country (in 000s tonnes)

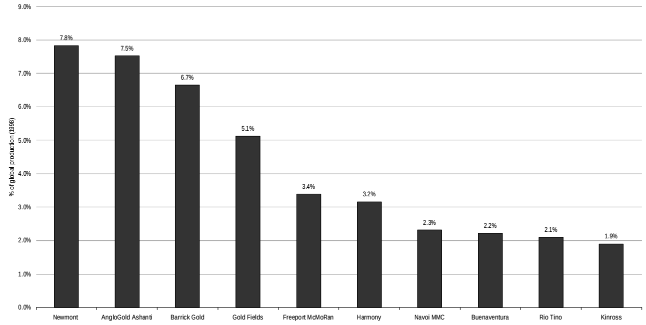
	Reserves	% of Total	Reserve Base	% of Total
United States	3,000	6.4%	5,500	5.3%
Australia	5,800	12.3%	6,000	5.8%
Brazil	2,000	4.3%	2,500	2.4%
Canada	1,000	2.1%	4,200	4.0%
Chile	2,000	4.3%	4,100	3.9%
China	1,900	4.0%	3,400	3.3%
Ghana	1,600	3.4%	2,700	2.6%
indonesia	3,000	6.4%	6,000	5.8%
Mexico	1,400	3.0%	3,400	3.3%
Papua New Guinea	1,200	2.6%	2,300	2.2%
Peru	1,400	3.0%	2,300	2.2%
Russia	5,000	10.6%	7,000	6.7%
South Africa	6,000	12.8%	31,000	29.7%
Uzbekistan	1,700	3.6%	1,900	1.8%
Other Countries	10,000	21.3%	22,000	21.1%
TOTAL	**47,000**	**100%**	**104,300**	**100%**

Source: GFMS 2009.

**Reserves refer to material that is economically viable at the time of determination, while Reserve Base includes reserves plus measured plus indicated resources that are marginally economic and some subeconomic resources.*
** Last publicly available Reserve Base data as of 2008.*
Source: USGS.

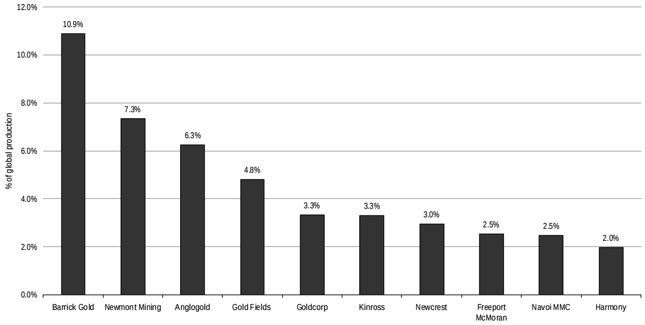
Despite the obvious decline in its production, South Africa still controls the largest portion of total known gold reserves (29.7%), although only 12.8% of this is made up of economically viable reserves. Australia and Russia hold the second and third largest amounts of economic reserves, with 12.3% and 10.6% of the world's total.

Exhibit 73: Top Ten Gold Producers (2005)



Source: GFMS.

Exhibit 74: Top Ten Gold Producers (2010)



Source: Company data, Credit Suisse estimates.

Consolidation among the major gold producers has resulted in significant changes in the composition of the top producers over the past five years. Despite the recent flurry of exploration and development companies, the top ten producers still account for approximately 40% of global gold production, essentially unchanged since 1998. Although there have not been any blockbuster mergers among the senior gold players in the past year, it has been an interesting environment, with corporate activity more focused on high-quality assets acquisitions, with near-term production or early-stage acquisitions by seniors and intermediates. The recent purchase by Kinross Gold of Red Back Mining and its Tasiast mine in West Africa is a perfect example of this trend. As a result, Kinross Gold currently is a significantly larger world-class senior producer, vaulting to the sixth position in 2010 from tenth in 2005..

Central Bank Holdings

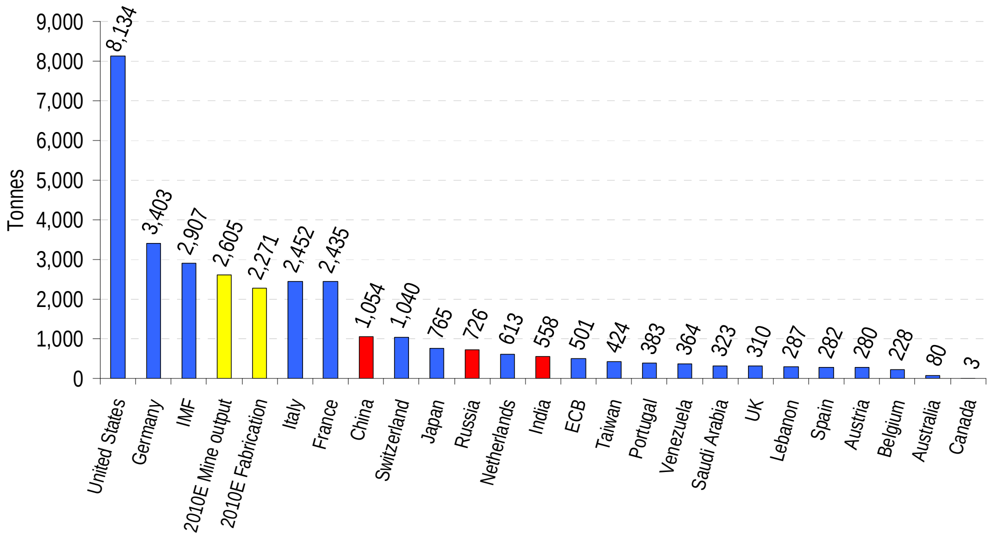
Exhibit 75: **Official Central Bank Gold Holdings (as of September 2010)**

Rank	Country	Reserves (tonnes)	% of Reserves
1	United States	8134	72.1%
2	Germany	3403	67.4%
3	IMF	2907	na
4	Italy	2452	66.2%
5	France	2453	65.7%
6	China	1040	1.5%
7	Switzerland	1040	15.1%
8	Japan	765	2.7%
9	Russia	726	5.7%
10	Netherlands	613	55.8%

Source: World Gold Council 2010.

According to the World Gold Council, roughly 58,500 tonnes of gold was held in reserves by central banks at the end of 2009. The United States remains the largest holder of gold, with more than 8,134 tonnes, approximately 72.1% of the country's total reserves. Contrastingly, Japan and China hold only 2.7% and 1.5% of total country reserves in gold.

Exhibit 76: **Global Central Bank Gold Reserves**



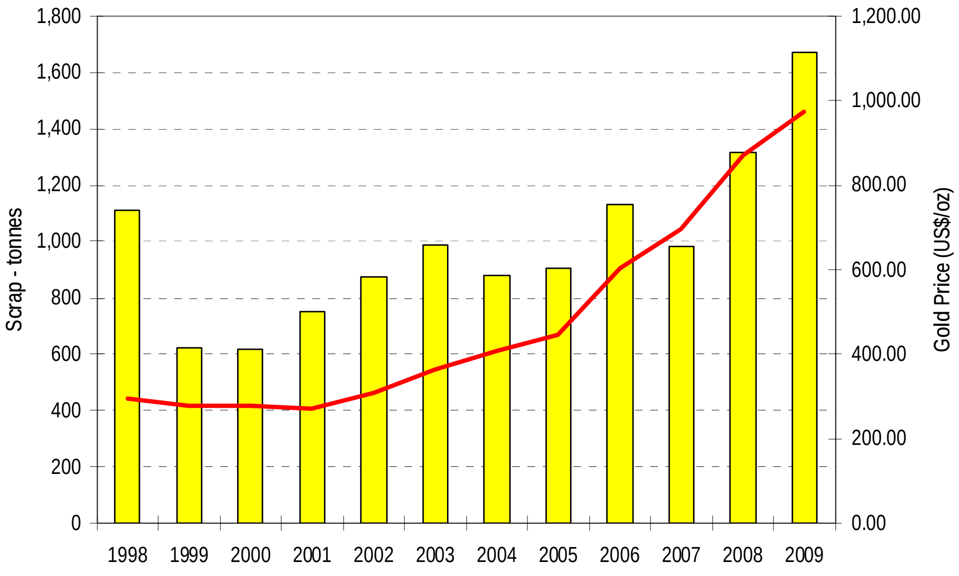
Source: World Gold Council 2010.

Rise of the ETF. The introduction and popularity of the gold ETF has been a significant driver of physical gold demand. Gold ETFs have experienced tremendous growth over the past five years and currently account for roughly 2,114 tonnes of physical gold, ranking them sixth, just behind France at 2,435 tonnes, in terms of gold holdings (according to the World Gold Council).

According to a recent study by the apex gold body and the World Gold Council (WGC), retail investors make up an estimated 70% of the SPDR Gold Trust exchange traded fund. The Gold Trust ETF is the second largest ETF of any kind, with over $56 billion under management, with only the SPDR S&P 500 ETF bigger at around $77 billion.

Recycled Gold (Scrap)

Exhibit 77: Supply of Gold Scrap



Source: GMFS 2010.

In prior years, gold scrap typically accounted for 25-35% of total gold supply (1999-2005). Exhibit 57 clearly illustrates how the supply of gold scrap metal shares a strong relationship to gold price increases (2001-03, 2005-06, and 2007-09); times of economic distress, when jewelry is often sold for scrap (i.e., a recent peak in scrap supply occurred in 1998, driven primarily by the Asian crisis of 1997-98); or times of extreme gold price volatility, as seen in 2006 and 2009. Scrap supply reached a new all-time high in 2009 of 1,674 tonnes, which we expect to be the peak, as scrap holder liquidations begin to exhaust.

Platinum Group Metals (PGMs)

The Platinum Group Metals (PGMs) comprise six separate metals: platinum, palladium, rhodium, iridium, ruthenium, and osmium. Platinum and palladium are by far the most common and most used of the PGMs. Platinum (Pt) is the 78th element of the periodic table and is among the rarest elements in the earth's crust. Palladium is the 46th element. Platinum and palladium are the only PGM's that are found naturally occurring and are found in thin layers of sulfide ores, typically in dark igneous rock.

Platinum

Periodic table symbol: Pt

Atomic number: 78

Palladium

Periodic table symbol: Pd

Atomic number: 46

Uses of PGMs

Transportation. The primary use of PGMs is to produce catalytic converters for automotive exhaust systems. The metals help to remove carbon monoxide, NOx, hydrocarbons, and particulates from the automobile's exhaust fumes.

Jewelry. Platinum and palladium's shiny, white, and noncorrosive surface makes them an attractive metal for jewelry design and wear. While in the past platinum dominated jewelry design, palladium recently has grown in popularity for jewelry owing to its lower price (primarily used in white gold).

Electrical. Small amounts of PGMs are used in the production of individual electronics owing to the metals' conductivity and durability. They are primarily used for multilayer ceramic capacitors. Capacitors help to control the flow of an electrical current through various parts of a circuit. Smaller amounts are used in conductive tracks in hybrid integrated circuits and for plating connectors. Platinum is used in the production of hard disk drives to improve their data storage capacity.

Chemical. Many chemical processes use PGMs to improve the efficiency of various reactions. One of the more common uses of PGMs is in the production of nitric acid, which is used for fertilizers and explosives. Various other chemical applications use PGMs, including the manufacture of paints, adhesives, fibers, and coatings. PGMs are also used in the production of precursors to polyester.

Dental. PGMs (mostly palladium owing to its relative cheapness) are usually mixed with gold or silver, as well as some base metals, to produce alloys used in dental inlays, crowns, and bridgework.

Investments. Similar to gold and other precious metals, investors hold physical interests in PGMs, normally through commodity ETFs, in order to speculate about their relative price. Other forms of investment include platinum and palladium coins and bars.

Other. PGMs are used in a variety of other applications, ranging from fuel cells to medicine and water treatment.

Primary Production Process

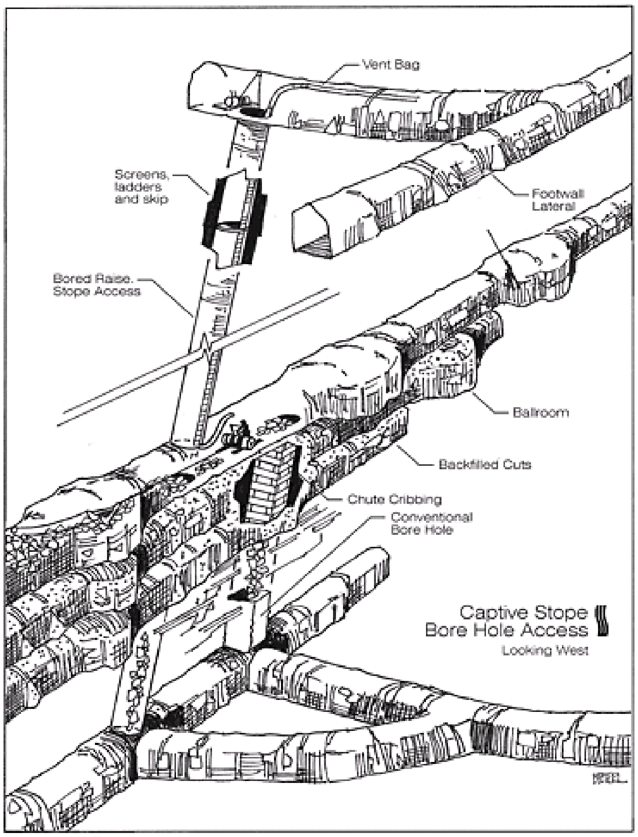
The mining and production of PGMs is similar to that of gold or copper, in that ore is removed from the earth through a variety of mining methods and then refined to a nearly pure form via a series of refining processes.

Mining Methods

Depending on the shape, size, ore grade, and composition of the ore body, a variety of mining methods can be used to remove the PGM-containing rock. The following provides an explanation of a few of the methods employed.

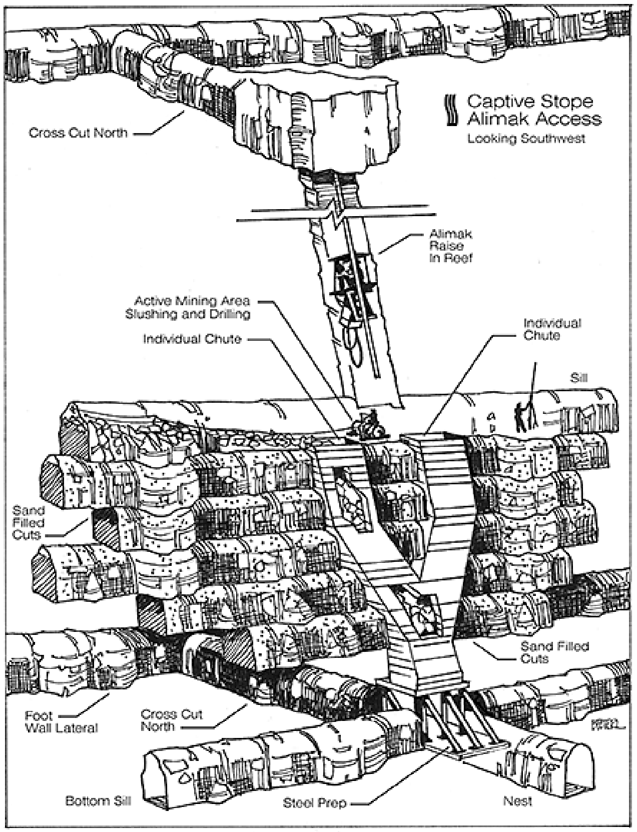
Captive Cut and Fill Method. This method involves extracting the ore body in 8-10 foot high horizontal cuts into the rock, which is accessed via verticle raises and mined with conventional drills and slushers. The open space created by each cut is then backfilled with waste rock from prior cuts and concentrator tailings, thus becoming the floor of the next level of mining as the process moves upwards. This is a relatively manpower-intensive form of mining.

Exhibit 78: Captive Cut and Fill with Bore-Hole Access



Source: Stillwater Mining.

Exhibit 79: Captive Cut and Fill with Alimak Access

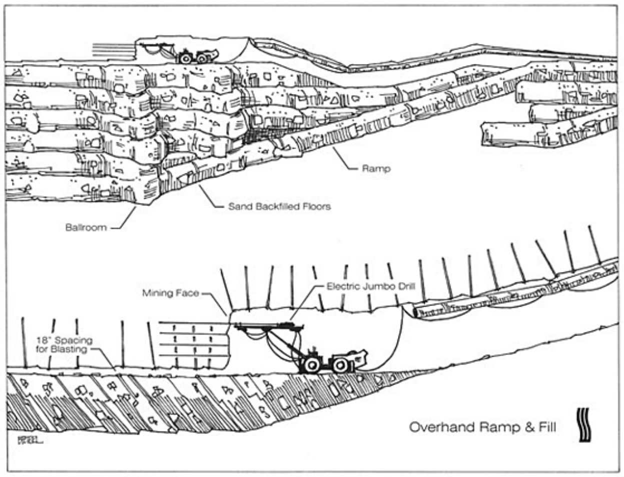


Source: Stillwater Mining.

Ramp and Fill Method. A series of horizontal cuts are extracted from the ore body using mobile equipment. Access to the ore body is via ramps driven within or adjacent to the ore body, which enables the use of hydraulic drills and load-haul-dump equipment. Advances are made in 9-foot increments, and after each level is mined out, similar to captive cut-and-fill, the empty space is then filled in with waste rock and sand to become the floor of the next horizontal cut.

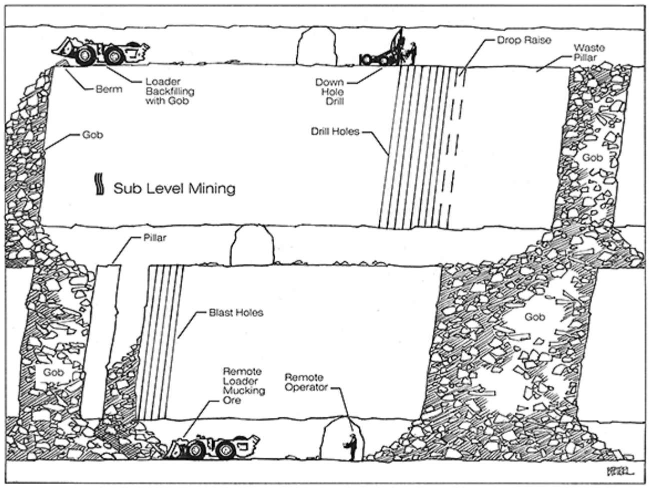
Sub-level stoping Method. This method involves extracting 50-75 foot blocks of ore in 30-foot intervals utilizing mobile long-hole drills and remote control rubber tired load-haul-dump equipment. The ore is mined in retreat sequence, and like other methods, backfilled with waste rock or sand.

Exhibit 80: Ramp and Fill



Source: Stillwater Mining.

Exhibit 81: Sub-Level Stoping



Source: Stillwater Mining.

Smelting and Refining

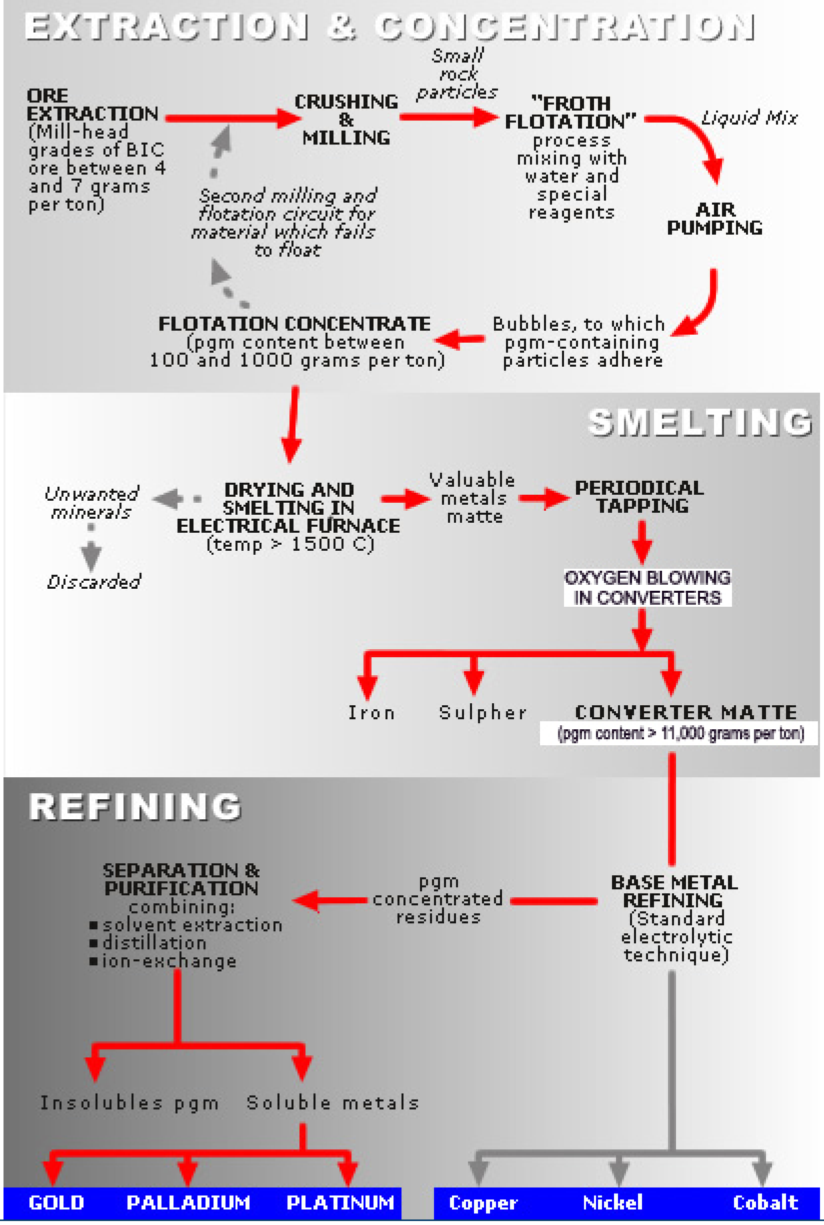
Following the mining of the unrefined ore from the mine, the rock must be put through a series of steps to purify the metal.

Extraction and Concentration. After the raw ore is removed from the mine, it is crushed and fed into a concentrator, mixed with water, and then ground to a slurry-like substance. This process frees the ore's PGM-bearing sulfide minerals from the rock. Various chemicals are then added to the slurry, which is then agitated in a froth-flotation circuit to separate the valuable sulfides from the waste rock. During this process, the minerals are floated, recycled, reground, and refloated repeatedly in order to produce a concentrate suitable for further processing.

Smelting and Refining. The concentrate left over from step one is shipped to a smelting complex, dried, and fed into an electric furnace. The feed is melted in a furnace, which separates out various components of the feed. The resulting PGM matte is tapped from the furnace and granulated and then remelted and processed in a top-blown rotary converter (TBRC), which separates iron from the converter matte. The converter matte is poured from the TBRC, granulated, and transferred to a base metals refinery for further processing. Even after concentration and smelting, the resulting material still only contains about 1.5% PGMs.

At the refinery, a sulfuric acid solution dissolves the converter matte, which separates out other metals mixed in with the PGM's, usually a mixture of base and other precious metals. These other metals are further refined using various methods and sold as byproducts of the PGM refining process. The resulting converter matte contains a much higher percentage of PGMs, about 40%. The end product of the refining process is a PGM-rich filter cake, which is then further refined at precious metals refineries, bringing the PGM purity up to 99.95%.

Exhibit 82: **PGM Ore Smelting and Refining Process**


EXTRACTION & CONCENTRATION
ORE EXTRACTION (Mill-head grades of BIC ore between 4 and 7 grams per ton)
CRUSHING & MILLING
Small rock particles
"FROTH FLOTATION" process mixing with water and special reagents
Liquid Mix
AIR PUMPING
Second milling and flotation circuit for material which fails to float
Bubbles, to which pgm-containing particles adhere
FLOTATION CONCENTRATE (pgm content between 100 and 1000 grams per ton)
SMELTING
Unwanted minerals
Discarded
DRYING AND SMELTING IN ELECTRICAL FURNACE (temp > 1500 C)
Valuable metals matte
PERIODICAL TAPPING
OXYGEN BLOWING IN CONVERTERS
Iron
Sulpher
CONVERTER MATTE (pgm content > 11,000 grams per ton)
REFINING
SEPARATION & PURIFICATION combining:
▪solvent extraction
▪distillation
▪ion-exchange
pgm concentrated residues
BASE METAL REFINING (Standard electrolytic technique)
Insolubles pgm
Soluble metals
GOLD
PALLADIUM
PLATINUM
Copper
Nickel
Cobalt

Source: Stillwater Mining Company Website.

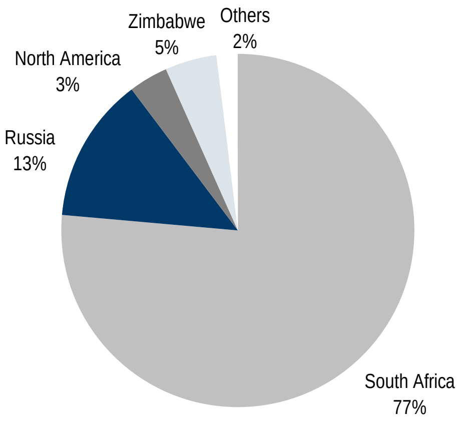
Global Supply—Mines and Recycling

Global supplies of PGMs come from a combination of new mine supplies and recycling of used metal.

PGM Mines

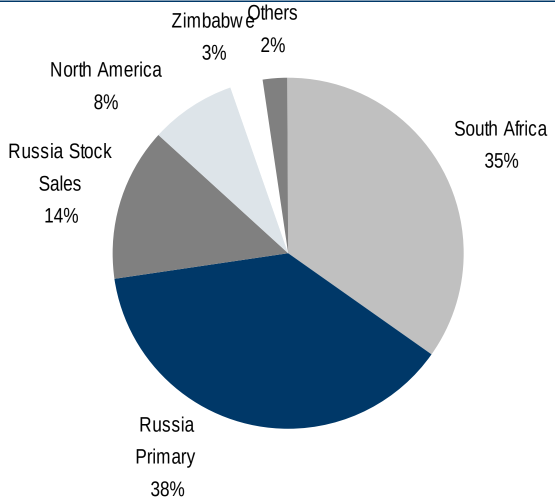
Mine supply is heavily consolidated both by region and by producer. From a geographic perspective, South Africa accounts for approximately 77% of global mined platinum and 40% of palladium (excluding Russia stock sales), with Russia accounting for 13% of platinum production and 38% of palladium mine production (excluding stock sales).

Exhibit 83: **Primary Platinum Supply**



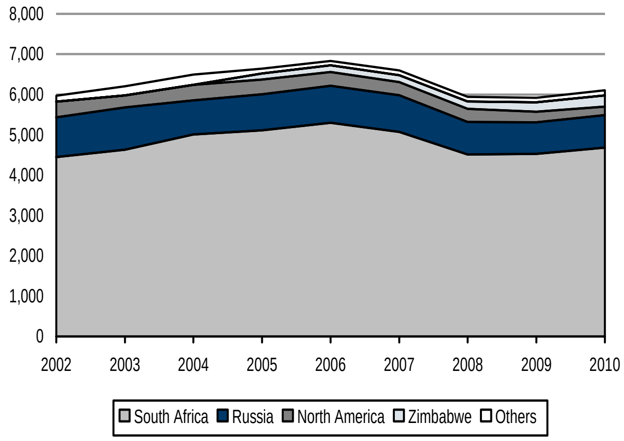
Source: Johnson Matthey.

Exhibit 84: **Primary Palladium Supply**



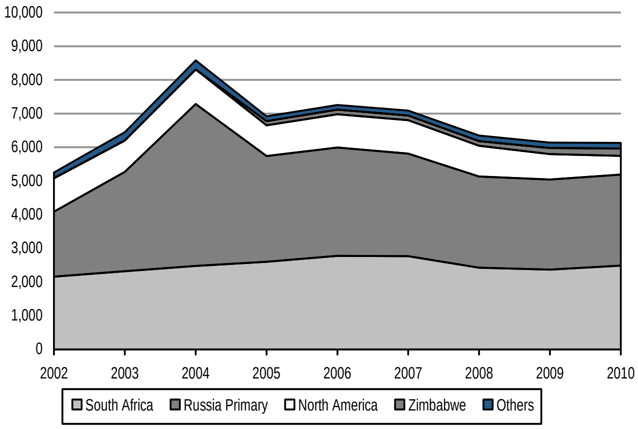
Source: Johnson Matthey.

Exhibit 85: **Platinum Mine Supply, 2002–2010**



Source: Johnson Matthey.

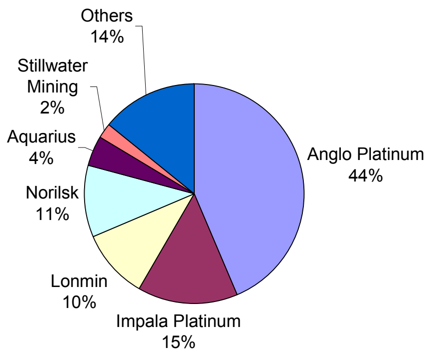
Exhibit 86: **Palladium Mine Supply, 2002–2010**



Source: Johnson Matthey.

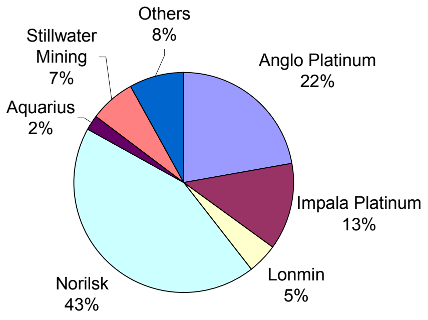
Global production of PGMs is also concentrated from a company perspective. The top five palladium producers account for approximately 90% of mine production, while the top five platinum producers account for approximately 85% of production. As a way of comparison, the top five copper producers account for only approximately 35% of global mined copper supplies.

Exhibit 87: Major Platinum Producers (2009)



Source: Company data.

Exhibit 88: Major Palladium Producers (2009)



Source: Company data.

Similar to global production dynamics, from a reserve perspective, the allocation of PGMs is highly concentrated among a few countries. Most notably, South Africa contains almost 90% of global PGM reserves, followed by Russia with approximately 10% of reserves. The United States holds only 1% of global PGM reserves.

Exhibit 89: Global PGM Reserves (kgs)

Country	Reserves	% of Total
South Africa	63,000,000	88.5%
Russia	6,200,000	8.7%
United States	900,000	1.3%
Canada	310,000	0.4%
Other	800,000	1.1%
Total	**71,210,000**	**100.0%**

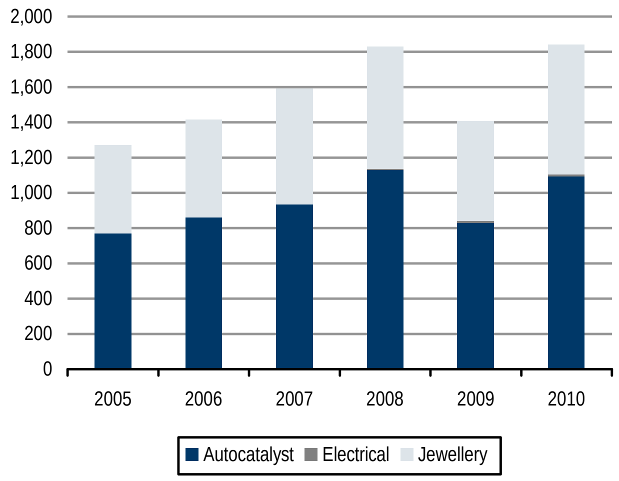
Source: USGS.

Recycling

In addition to mine supplies, a fairly significant and growing portion of total PGM supplies comes from recycling of used PGM material. As can be seen in the graphs below, a majority of the recycled material comes from spent autocatalytic converters from used automobiles, with additional supply coming from old jewelry and electrical equipment. The supply of recycled material fluctuates with the current price of platinum and palladium, as higher prices provide suppliers with an incentive to extract old material and supply it to the market.

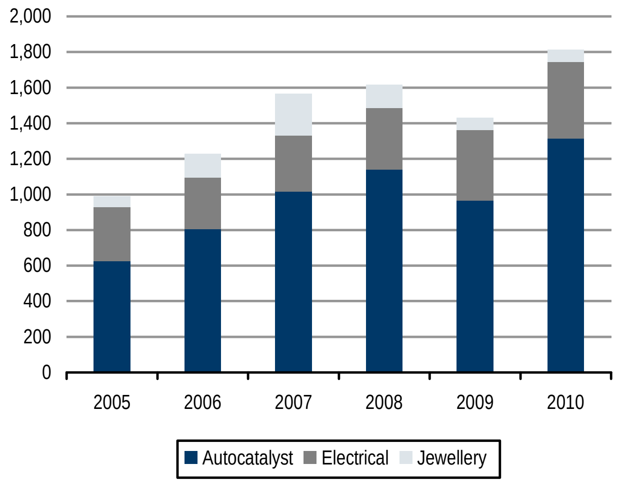
With the rise of PGM prices, the supply of recycled material has grown fairly significantly over the past eight years. In 2002, recycling accounted for roughly 9% of total platinum supplies. However, by 2010, recycling platinum accounted for approximately 23% of total global supplies. The growth in palladium recycling as a proportion of total supplies is roughly the same as platinum, growing to 20% by 2010 from 7% of supplies in 2002.

Exhibit 90: Platinum Recycling



Source: Johnson Matthey.

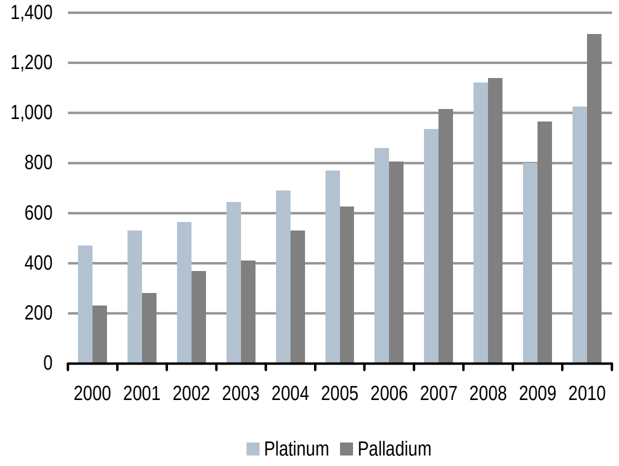
Exhibit 91: Palladium Recycling



Source: Johnson Matthey

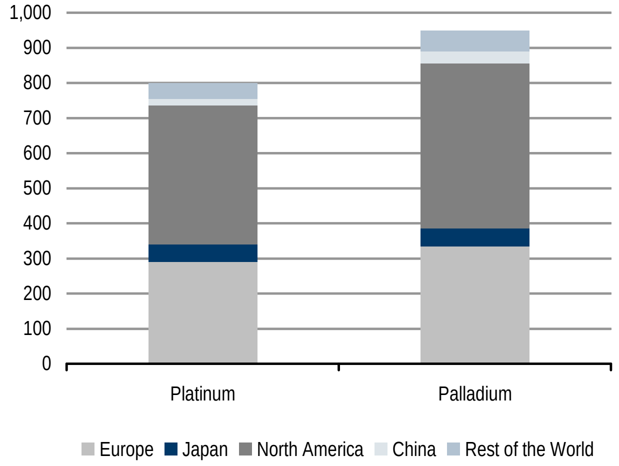
Europe and North America account for the vast majority of autocatalytic recycling, as shown in Exhibit 93. Given the approximately ten-year recycling time for used cars and the composition of global car sales some ten years ago, it is not surprising these two regions dominate the recycling market.

Exhibit 92: Catalytic Converter Recycling



Source: Johnson Matthey.

Exhibit 93: 2009 Split by Geography

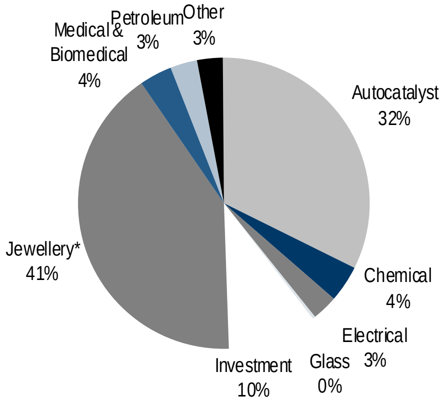


Source: Johnson Matthey.

Global Consumption and End Markets

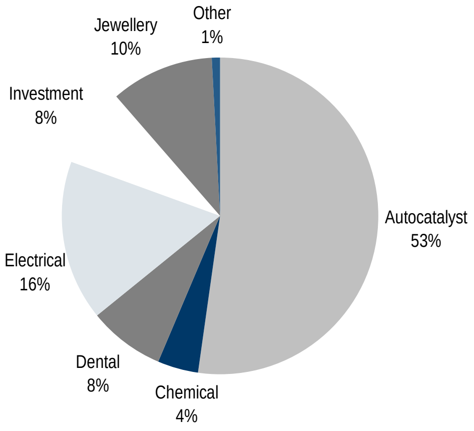
PGMs have four primary end markets: auto, jewelry, investments, and electrical/industrial.

Exhibit 94: Platinum Demand by End Market—2009



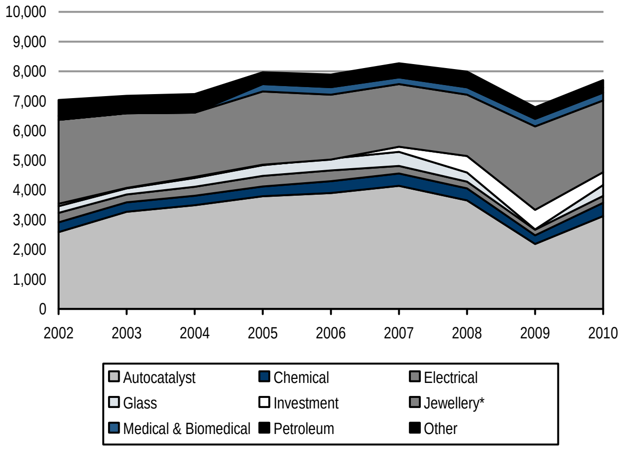
Source: Johnson Matthey.

Exhibit 95: Palladium Demand by End Market—2009



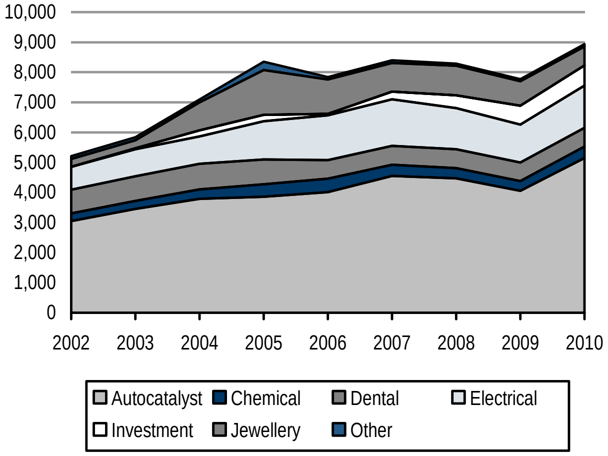
Source: Johnson Matthey.

Exhibit 96: Platinum Demand, 2002–2010



Source: Johnson Matthey.

Exhibit 97: Palladium Demand, 2002–2010



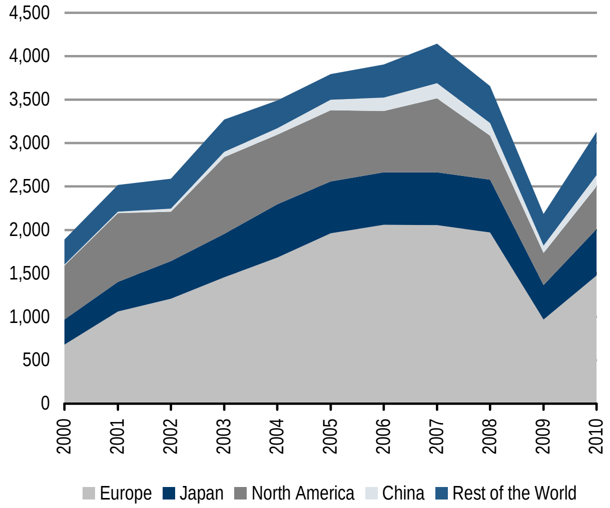
Source: Johnson Matthey.

Auto industry

Palladium and platinum are essential catalysts in the conversion of carbon monoxide, unburned hydrocarbons, and reduction of NOx from automobile exhaust fumes. As demonstrated in the above charts, catalytic converters are the larger source of demand globally for PGMs, comprising roughly 53% of palladium demand and 32% of platinum demand.

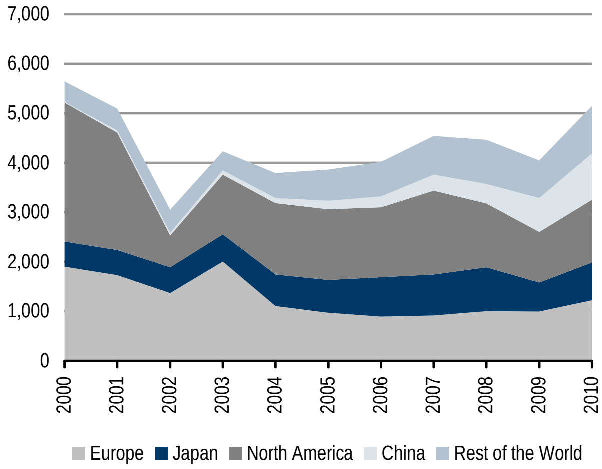
Platinum is more effective than palladium in most cases, but costs are clearly an important consideration, and there is often a trade-off between the two. Generally, diesel technologies favor platinum, with cleaner gasoline engines using a predominately palladium filter.

Exhibit 98: Platinum by Region—Autocat Demand



Source: Johnson Matthey.

Exhibit 99: Palladium by Region—Autocat Demand



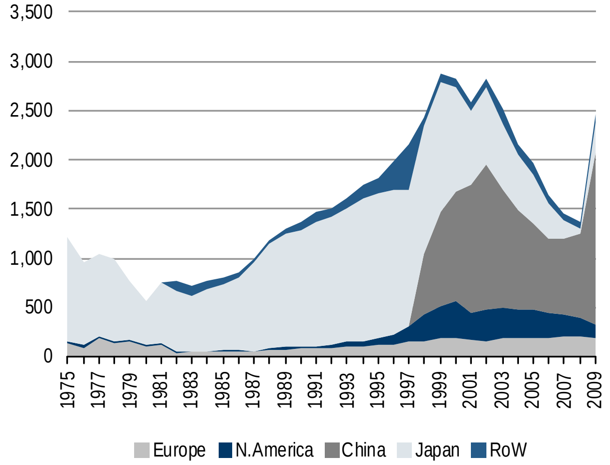
Source: Johnson Matthey.

As demonstrated in Exhibit 98 and Exhibit 99, the auto industry has recently begun switching from using platinum as its primary metal to palladium, given the historical price differential between the two. There is a degree of substitutability between platinum and palladium. The ratio historically stood at 3 (i.e., if the price of platinum was 3 times or more than the price of palladium, auto producers would switch to palladium). However, in recent years, the combination of technological gains and cleaner-burning fuels have resulted in the substitution ratio dropping as low as 1:1 in some uses. In our view, a price ratio of above 1.5-2.0 will continue to drive substitution away from platinum and into palladium.

Jewelry

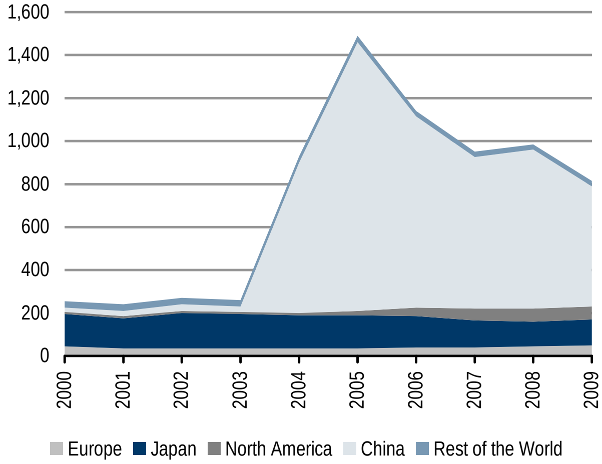
Jewelry represents the second major source of demand for PGMs. Demand is mainly concentrated on the platinum side, with jewelry accounting for approximately 30% of platinum demand through the cycle, while only accounting for 13% of palladium demand. (Palladium is predominantly used in white gold.) In contrast to autocat demand, jewelry is a relatively price-sensitive source of demand and acts as a demand/price buffer in times of accelerating industrial demand (2003-08) or economic recession (2002, 2009).

Exhibit 100: Platinum Jewelry Demand



Source: Johnson Matthey.

Exhibit 101: Palladium Jewelry Demand

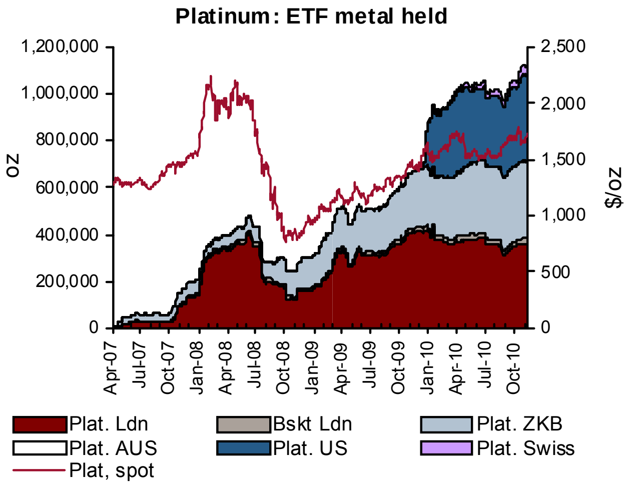


Source: Johnson Matthey.

Investments

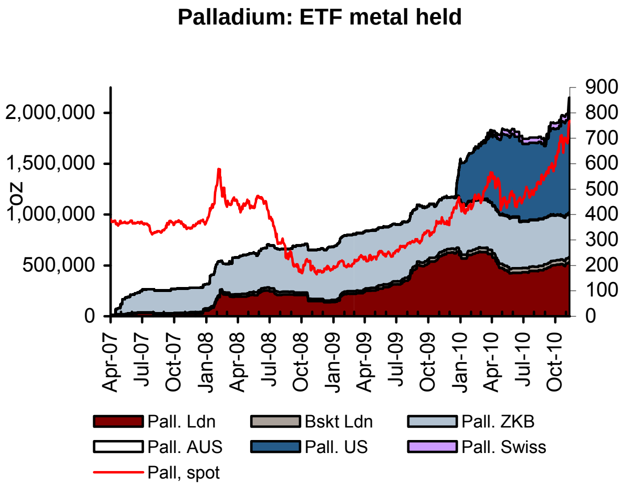
Investment demand, in the form of commodity ETFs, accounts for roughly 8% of palladium consumption and 10% of platinum consumption. As shown in Exhibit 102: Platinum ETF Demand and Exhibit 103, the demand of investors to hold PGMs is fairly highly correlated with the relevant price of platinum and palladium over time.

Exhibit 102: Platinum ETF Demand



Source: Johnson Matthey.

Exhibit 103: Palladium ETF Demand



Source: Johnson Matthey.

Electrical, Petroleum, Chemical, Dental, and Glass Demand

General industrial demand for PGMs comes from a variety of disparate sectors, such as electronics, chemicals, and dental, each of which alone comprise a relatively small portion of total PGM consumption. However, in total, industrial consumption of PGMs accounts for approximately 25-30% of demand. Electrical, petroleum, chemical, glass, and other industrial demand accounts for 5%, 3%, 4%, 6%, and 6% of platinum demand, respectively. Electrical, chemical, dental, and other industrial demand accounts for 15%, 4%, 9%, and 1% of palladium demand, respectively.

Silver

Periodic table symbol: Ag

Atomic number: 47

Silver has been used throughout history in industrial applications, as a mode of currency, in jewelry, and for investment purposes. Silver's unique physical and chemical properties make it a metal that has few substitutes and many applications. The onset of the industrial revolution marked a major turning point in which technological advances expanded the use of silver dramatically. Silver is currently used in electrical contacts and conductors and as a catalyst in chemical reactions. Silver's compounds are used in photographic film and dilute silver nitrate solutions. Other silver compounds are used as disinfectants and for medical antimicrobial uses, where research still continues.

Silver is unique amongst metals owing to its classification as both a precious metal and industrial metal. Silver has the highest electrical and thermal conductivity of any metal, is the most reflective and sensitive to light, and is a very strong metal with a high degree of ductility and malleability. The unique reactivity of the metal is the basis for its use in photography and as a catalyst. Silver's effectiveness as a bactericide and algaecide also makes it very useful in medical and sterilization applications.

Industrial uses of silver

Silver used in diverse applications such as imaging, electronics, jewelry, coinage, superconductivity, and water purification

Batteries. Most batteries, rechargeable and disposable, are manufactured with silver alloys as the cathode. Silver cells have power-to-weight characteristics that are superior to others. The most common of these batteries is the small button-shaped silver-oxide cell which is used in cameras, toys, hearing aids, watches, and calculators, which contain approximately 35% silver. Owing to environmental and safety concerns, silver-oxide and silver-zinc batteries are beginning to replace lithium-ion batteries in mobile phones and laptop computers.

Bearings. Steel ball bearings electroplated with silver have greater fatigue strength and load carrying capacity than steel substitutes. These bearings are most used in continuous, heavy-duty applications such as jet engines. Because steel has a poor coefficient of friction, placing a layer of silver between the steel and housing reduces friction, increasing performance and longevity.

Brazing and Soldering. Brazing is the joining of materials when done at temperatures above 600°C, which provides a smooth, leak-tight, and corrosion-resistant joint. Silver is used as a facilitator in the process. Silver brazing alloys are used widely in applications ranging from air-conditioning and refrigeration to electric power distribution. It is also used in the automobile and aerospace industries. Silver brazes and solders combine high tensile strength, ductility, and thermal conductivity. Silver-tin solders are used for bonding copper pipe and faucet pipe in homes, replacing harmful lead-based solders, while providing the piping with silver's natural antibacterial action.

Catalysts. Silver is an increasingly important catalyst for many industrial chemical processes, primarily used in the chemical and plastics industry for the production of ethylene oxide and formaldehyde. Ethylene oxide is used for flexible plastics such as polyester textiles for clothing and specialty fabrics, for molded items such as handles for stoves, key tops for computers, and electrical control knobs. Approximately 25% of ethylene oxide is used to produce antifreeze coolant for automobiles. Formaldehyde is used on solid plastics, including adhesives, laminating resins for plywood, and particle board, which helps to produce required finishes for paper, electronic equipment, textiles, surface coatings, dinnerware and buttons, casings for appliances, handles and knobs, packaging materials, automotive parts, thermal and electrical insulating materials, toys, and many other products.

Electronics. Owing to silver's excellent electrical conductivity, it is found in many electronic applications, including printed circuit boards, switches, and TV screens. For printed circuit boards, silver-based inks and films are applied to composite boards to create electrical pathways. The silver-based inks are also used for radio-frequency identification (RFID) tag antennas. Silver membrane switches are used in buttons on televisions, telephones, and microwave ovens. Silver is also used to coat CDs, DVDs, and in plasma display panels used in television sets and monitors.

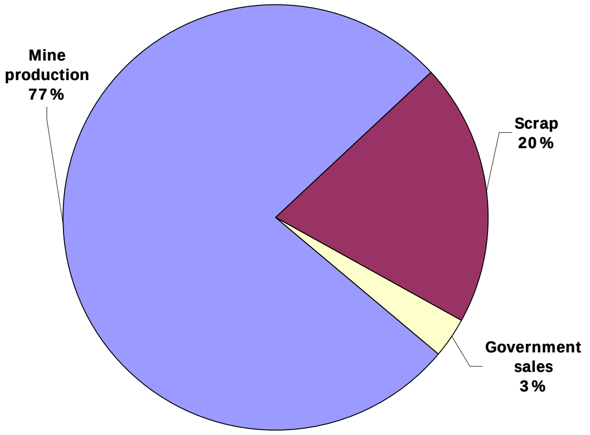
Supply

Over 2/3rds of silver production comes from non-silver mines

Total annual silver supply of approximately 930Moz comes from mining, scrap-recycling, and disinvestment, mainly in the form of government and Central Bank sales. (See Exhibit 104.) We estimate total silver supply increased 4.5% in 2010, and we forecast a slightly lower increase for 2011, as new mine supply should be offset by lower scrap and government sales supply.

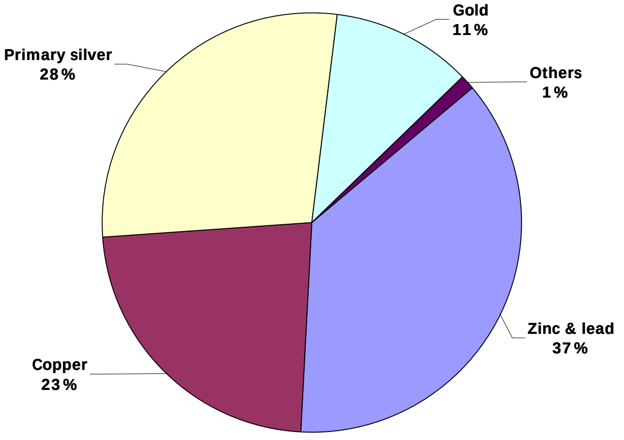
Mining contributes 77% of total supply, of which about 70% comes as byproduct from base metal and gold mines. (See Exhibit 105.) There are few mines in the world that primarily mine silver. As a result, we view silver production as relatively inelastic to price movements. Furthermore, economic slowdown and supply shocks at base metals and gold mines could result in reduced silver mine supply. In 2009, silver generated at primary mines posted a 1% decline year over year to account for 28% of total mine production. Most mined silver emerges as a byproduct from lead/zinc operations (37%) and copper (23%). Cash costs at primary silver mines are about $6/oz.

Exhibit 104: **Silver Supply Sources**



Source: GFMS.

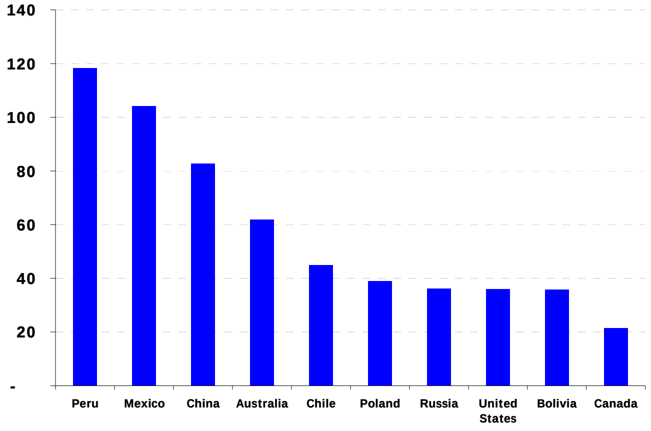
Exhibit 105: **Silver Mine Supply Sources**



Source: GFMS.

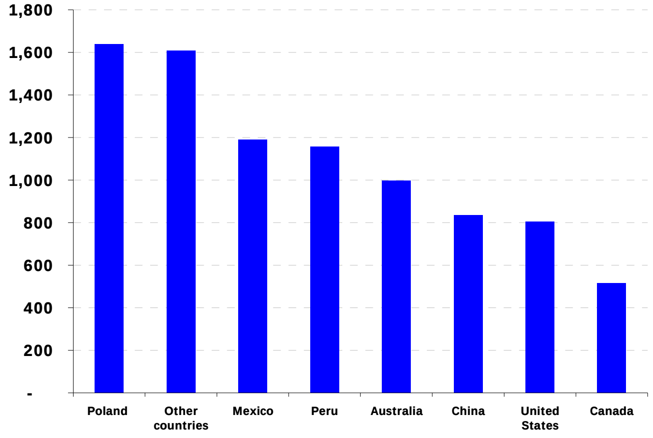
Geographically, just less than 60% of mined silver comes from the Americas, including Peru, Mexico, Chile, the United States, Bolivia, and Canada. (See Exhibit 106.) On our estimates, mine production is forecast to rise by 2% in 2011 to 955Moz. Supply from primary silver producers is forecast to increase, notably from SSO’s Pirquitas, PAA’s Manantial Espejo, and Couer d’Alene’s San Bartolomé. Production contribution from gold mining includes Goldcorp’s Peñasquito, Couer d’Alene’s Palmarejo, Minefinders’ Dolores, and Agnico-Eagle’s Pinos Altos.

Exhibit 106: **Top Ten Silver Producing Countries**



Source: GFMS.

Exhibit 107: **Global Silver Resources by Country**

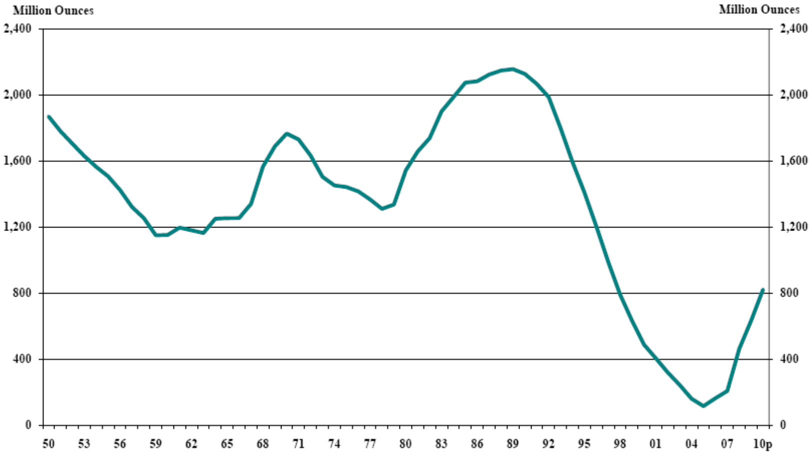


Source: GFMS.

For the past several years, the supply/demand deficit has been filled by the selling of stockpiles, mostly from government. According to CPM Group (2008), world silver bullion stockpiles were approximately 1,900Moz in 1950, but the current total is estimated to be about 200Moz, although we suspect this may be a conservative estimate owing to limited data of stockpiles inventory in China and Russia.

Silver bullion stockpiles have fallen dramatically over past 20 years

Exhibit 108: **Total Silver Bullion Inventory**



Source: CPM Group.

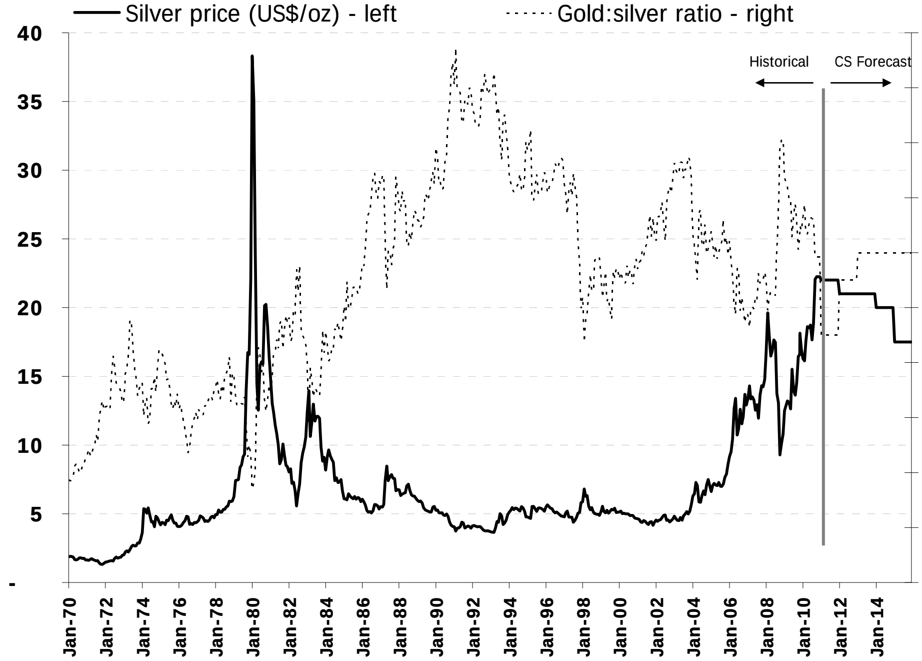
GFMS estimates world scrap supply increases of 11% in 2010 to approximately 177Moz, roughly equivalent to 20% of mine supply. We estimate silver scrap supply increased by 9% in 2010, with an expected small decline in 2011 as the amount of silver recovered from photographic waste continues to decline. Scrap supply is strongly linked to the silver price and mine supply.

Silver scrap makes up 20% of total supply

GFMS estimates government sales to rise slightly in 2010 by approximately 5Moz. According to GFMS, disposals by Russia account for the bulk of government sales. Going forward, we anticipate a flat 14Moz in government sales as inventory levels reach relatively low levels.

Government sales make up less than 5% of total supply

Exhibit 109: **Silver Price and Gold:Silver Ratio**



Source: Credit Suisse estimates.

Gold:silver ratio
Historical avg.: 55:1
5-Year avg.: 59:1
2-Year avg.: 64:1

Copper:silver ratio
Historical avg.: 397:1
5-Year avg.: 482:1
2-Year avg.: 406:1

Exhibit 110: **Silver Supply and Demand Model**

	2004	2005	2006	2007	2008	2009	2010E	2011E	2012E	2013E	2014E
Supply analysis (Mln ounces)											
Mine production	634	650	647	664	685	710	734	764	787	810	835
Net official sector sales	62	65	78	42	28	14	14	14	14	14	14
Silver scrap	181	175	188	182	176	166	182	178	173	169	165
Producer hedging	2	5	-	-	-	-	-	-	-	-	-
Implied net dis-investment (ETF's+OTC)	-	-	-	-	-	-	-	-	-	-	-
sub-total	879	895	914	888	888	889	930	955	974	993	1,013
Other	-	-	-	-	-	-	-	-	-	-	-
Total supply	**879**	**895**	**914**	**888**	**888**	**889**	**930**	**955**	**974**	**993**	**1,013**
Demand analysis (Mln ounces)											
Industrial applications	367	375	425	454	443	352	423	473	502	532	564
Photography	181	175	144	125	105	83	74	71	68	65	63
Jewelry & silverware	248	260	228	222	215	216	213	218	222	226	231
Coins & medals	41	43	40	40	65	79	97	106	112	114	116
Total fabrication demand	837	853	836	840	829	730	806	868	903	937	974
Net official sector purchases	-	-	-	-	-	-	-	-	-	-	-
Producer de-hedging	-	-	7	24	12	22	24	24	24	24	24
Implied net investment (ETF's+OTC)	42	42	71	25	48	137	100	70	60	60	60
Total consumption	**879**	**895**	**914**	**888**	**888**	**889**	**930**	**962**	**987**	**1,021**	**1,058**
Market balance											
Implied silver market surplus (deficit)	-	-	-	-	-	-	0.0	(6.9)	(13.7)	(28.5)	(44.5)
Percent of market demand (%)	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*-0.7%*	*-1.4%*	*-2.8%*	*-4.2%*
Silver price (US$/oz)	6.68	7.32	11.59	13.37	14.99	14.69	19.25	22.00	21.00	21.00	20.00
Silver price (YoY% change)	*37%*	*10%*	*58%*	*15%*	*12%*	*-2%*	*31%*	*14%*	*-5%*	*0%*	*-5%*

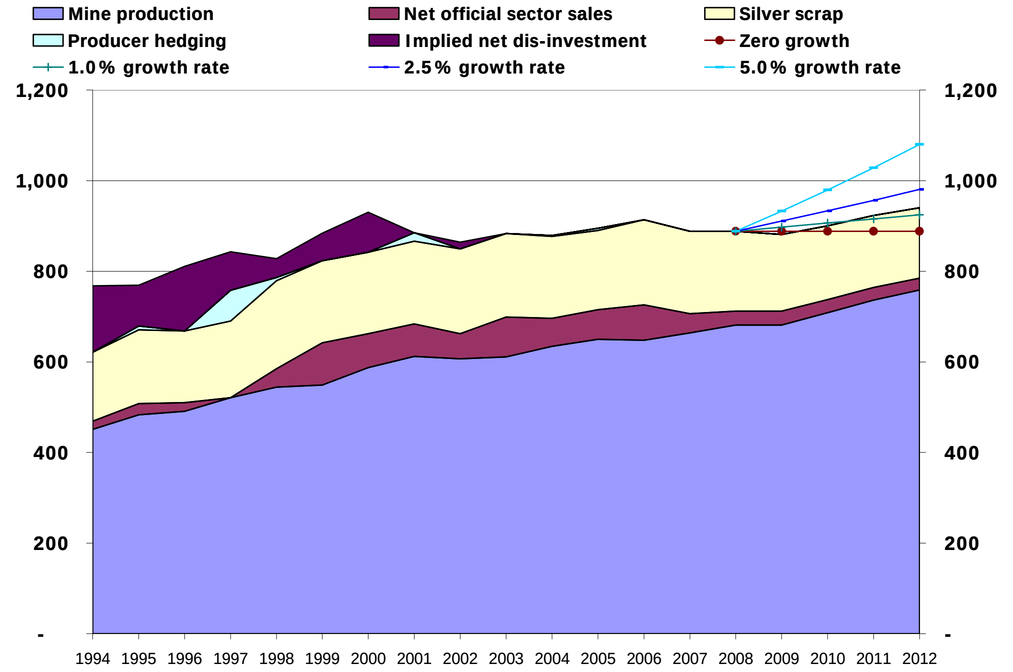
Source: GFMS, Credit Suisse estimates.

Demand

Silver fabrication demand accounts for over 85% of total silver demand, with producer dehedging and net investment accounting for the remainder. We further consider fabrication demand to be broken down into four key markets: (1) industrial; (2) photography; (3) jewelry & silverware; and (4) coins & medals. Historically, fabrication demand has grown at an average annual rate of 1.5%. The other elements of demand (government purchases, producer dehedging, and investment) are alike in that, on a net basis, they may not be featured every year on the demand side. According to GFMS, the official sector has not generated net purchases since 1997. As previously mentioned,

Fabrication demand accounts for over 90% of total silver demand investment demand has been a key driver in silver's recent rally, and this stands in contrast to the sustained net disinvestment seen in the 1990s. (See Exhibit 111.)

Exhibit 111: **Silver Supply and Demand Analysis**



Source: GFMS, Credit Suisse estimates.

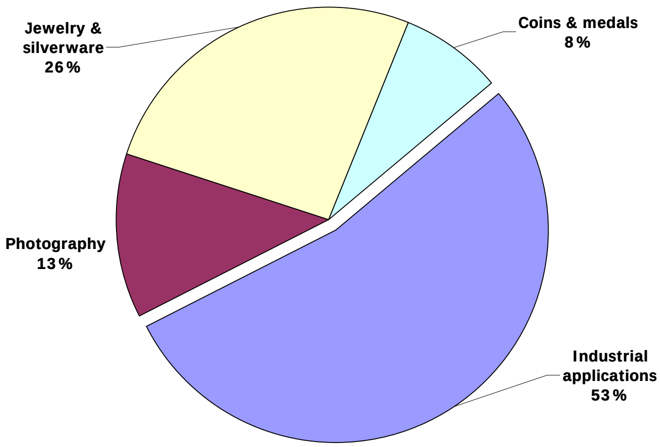
In 2010, silver fabrication demand increased 49%, led by a 5% increase in industrial demand offset by a 1% decline in photography. In 2011, we forecast a further increase of 6.6%, with industrial demand to increase 11%. Industrial demand increased on higher electrical and electronics demand and improvements in global GDP and IP, restocking, and supportive exchange rate movements are expected to provide the catalysts for the 11% rebound in industrial demand in 2011.

Jewelry demand makes up 23% of fabrication demand

Jewelry and silverware is traditionally made from sterling silver (or standard silver), an alloy of 92.5% silver and 7.5% copper. Jewelry and silverware fabrication is forecast to show modest growth of 3% in 2011. Higher silver prices are expected to slow demand growth; however, we expect this to be offset by higher gold prices, which is allowing for substitution away from gold.

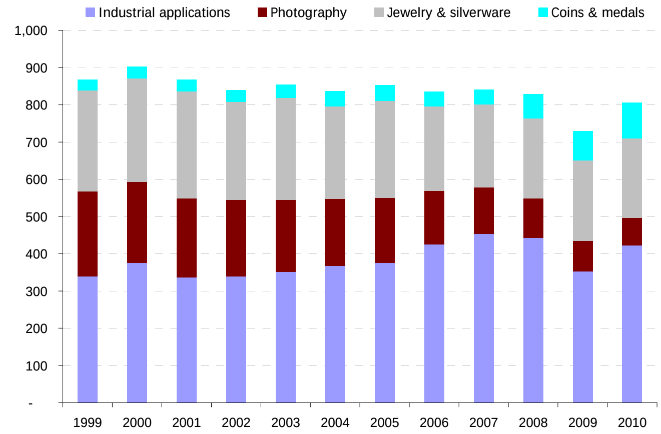
Silver-based photography is based on light striking sensitive silver-halide crystals suspended on a film. After falling 10% in 2009, we expect photographic use of silver to gravitate toward trend-line decline of 4% beginning in 2010. Owing to the growth of digital photography and the use of low-cost, ink-jet printers, silver-based imaging by consumers has been steadily dropping since 2000. (See Exhibit 113.)

Exhibit 112: **Silver Fabrication Demand**



Source: Silver Institute, Credit Suisse estimates.

Exhibit 113: **Silver Fabrication Demand (1999–2009E)**



Source: Silver Institute, Credit Suisse estimates.

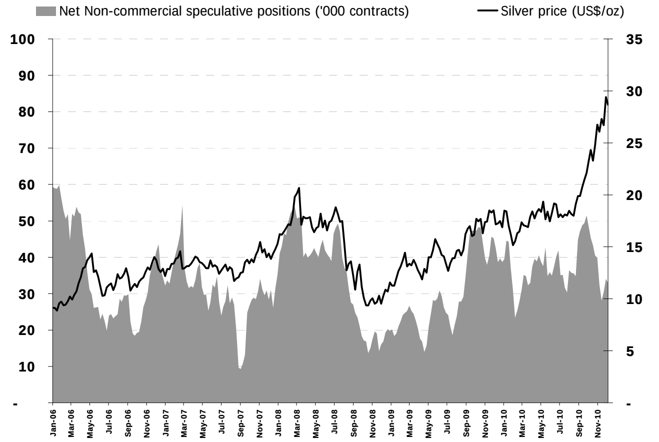
Investment

Silver exchange traded funds (ETFs) are a relatively new investment vehicle allowing investors to invest in silver without holding the metal or taking positions in the derivatives markets (futures, options, or forwards). There are several ways for investors to play silver with ETFs, the most popular and liquid being the iShares Silver Trust (NYSE:SLV). This trust is not actively managed, and the physical silver is held on deposit.

Current ETF holdings approaching 400Moz

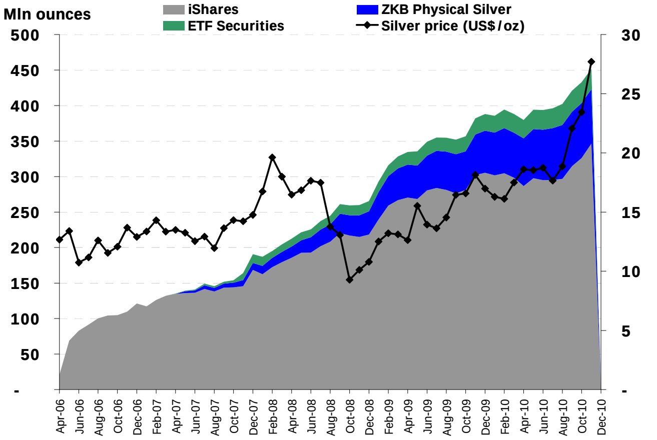
Noncommercial positions (reported weekly by Commodities Futures Trading Commission [CFTC]) serve as a good proxy for investor positions and sentiment in silver, and in some cases, has functioned as a good leading indicator of short-term movements in the silver price. (See Exhibit 114.)

Exhibit 114: **Net Speculative Positions on COMEX**



Source: Bloomberg, COMEX, Credit Suisse estimates.

Exhibit 115: **Silver Holdings in Selected Silver ETFs**



Source: GFMS, Credit Suisse estimates.

Bulk Commodities

- **Coal**
- **Molybdenum**
- **Uranium**

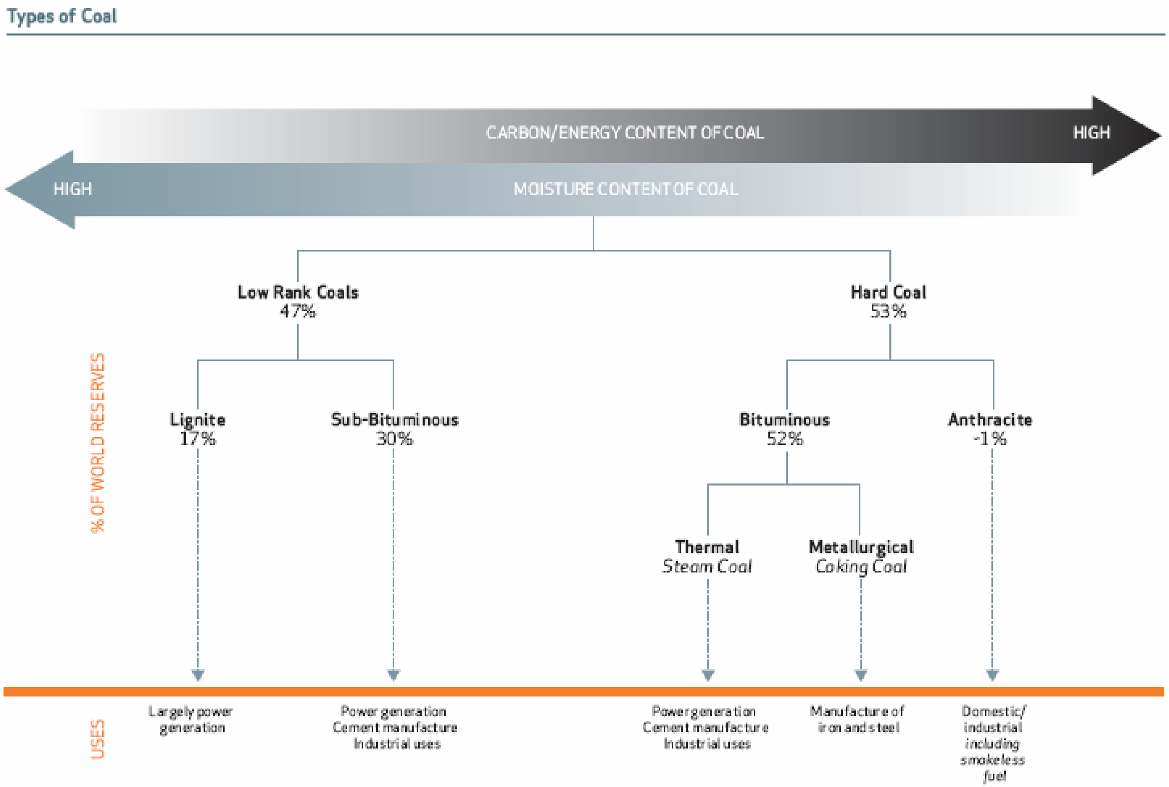
Coal

Coal is a fossil fuel formed by the geologic effects of temperature and pressure of the earth's surface on the remains of prehistoric vegetation (peat and moss), buried through tectonic movements among other rock strata over millions of years, resulting in the creation of coal seams. This process is known as coalification.

Types of Coal

There are four primary types of coal, each with specific uses based on their quality and characteristics. (See Exhibit 116.) The physical and chemical properties of each type reflect the length of time the peat has been under pressure, resulting in a ranking of coal from low rank to high rank, with highest-rank coal typically being the oldest. High-rank coals are stronger, have less moisture content, higher carbon content, and therefore more heat content. Conversely, low-rank coals tend to be softer, with lower carbon content and higher moisture content.

Exhibit 116: **Overview of Coal Types**


Types of Coal
CARBON/ENERGY CONTENT OF COAL
HIGH
HIGH
MOISTURE CONTENT OF COAL
% OF WORLD RESERVES
Low Rank Coals 47%
Hard Coal 53%
Lignite 17%
Sub-Bituminous 30%
Bituminous 52%
Anthracite -1%
Thermal Steam Coal
Metallurgical Coking Coal
USES
Largely power generation
Power generation Cement manufacture Industrial uses
Power generation Cement manufacture Industrial uses
Manufacture of iron and steel
Domestic/ industrial including smokeless fuel

Source: World Coal Institute.

Exhibit 117: **Anthracite Coal**

Source: Mineral Information Institute.

Exhibit 118: **Bituminous Coal**

Source: Mineral Information Institute.

Anthracite. Least common of the types (less than 1% of world's coal reserves), contains 86-97% carbon, with a slightly lower heating value than that of bituminous coal.

Bituminous. The world's most commonly found coal (52% of world's reserves), containing anywhere from 45% to 86% carbon content. In the United States, typically found in the eastern Appalachian regions, including both thermal and metallurgical coal grades.

Subbituminous. In the United States, subbituminous coal is primarily found in the Powder River Basin. Subbituminous coal generates less heat per pound when compared with bituminous coal, but also has lower sulfur content and only 35-45% carbon content.

Lignite. In the United States, lignite is primarily found in the Gulf Coast and, to a lesser extent, the Powder River Basin. It is crumbly, has high moisture content, generates the least heat content per pound of all the coal types, and has only 25-35% carbon.

Primary Production Process (Thermal and Metallurgical Coal)

Underground mining currently accounts for about 60% of the world's coal production, although in several important coal producing countries surface mining is more common. Surface mining accounts for roughly 80% of production in Australia, while in the United States surface mining accounts for approximately 72% of production. This compares with a 50/50 split between surface and underground mining in the United States in 1973.

Surface Mining

In surface mining, explosives are first used to break up the overburden, with large pieces of equipment (such as draglines, power shovels, trucks, etc.) then used to clear out the residual overburden in order to expose the underlying coal seam. The seam is then drilled and mined through a number of methods, including strip mining, contour mining, area mining, and auger and highwall mining.

Mountaintop removal mining (MTR). A variance of surface mining found primarily in Central Appalachia, MTR mining involves the removal of upper layers of rock from mountaintops through explosives, thereby uncovering the coal seams beneath. The excavated overburden is then used as filler in upper portions of adjacent valleys, essentially leveling previous mountainous areas.

Underground Mining

In underground mining, three methods are traditionally used to access the ore: (1) drift mines, which tunnel horizontally into the ridge; (2) shaft mines, which access the ores vertically; and (3) slope mines, which access the ores via a sloping track.

Once the ore is accessible, there are two primary underground coal mining methods:

1. *Conventional room and pillar mining.* This is the traditional method, which involves tunneling through the seam on a room-by-room basis, leaving pillars of coal and roof bolts to hold up the overlying rock. The pillars are often thick, making up as much as 40% of the total coal in the seam. Drilling and blasting is used to break up the exposed coal (the face), which is then loaded onto shuttle cars that extract the coal back to the surface. Once the seam is fully depleted, in some cases the miners will mine out the pillars as they retreat, allowing the roof behind it to collapse.

2. *Longwall mining.* In areas with larger coal seams (typically block panels ranging in size from 1,000 feet wide and 10,000 feet long) and where the geology is conducive, longwall mining is used. Longwall mining is a highly efficient, automated mining technique that involves the use of large machinery that moves along the entire 1,000 foot-width face of the coal seam, scraping the coal from ceiling to floor with mechanical shearers. The coal is then advanced to the surface via a conveyor system. As the coal is sheared, the longwall advances, with floor to ceiling roof supports adjusting as needed, allowing the roof of the mine behind the supports to collapse.

Coal Preparation

Coal straight from the ground, known as run-of-mine (ROM) coal, often contains unwanted impurities such as rock and dirt and comes in a mixture of different-sized fragments. Coal preparation, also known as coal beneficiation or coal washing, refers to the treatment of ROM coal to ensure a consistent quality and to enhance its suitability for particular end uses. The treatment depends on the properties of the coal and its intended use. It may require only simple crushing, or it may need to go through a complex treatment process to reduce impurities.

To remove impurities, the raw run-of-mine coal is crushed and then separated into variously sized fractions. Larger material is usually treated using dense medium separation. In this process, the coal is separated from other impurities by being floated in a tank containing a liquid of specific gravity, usually a suspension of finely ground magnetite. As the coal is lighter, it floats and can be separated off, while heavier rock and other impurities sink and are removed as waste. The smaller-sized fractions are treated in a number of ways, usually based on differences in mass, such as in centrifuges. A centrifuge is a machine that turns a container around very quickly, causing solids and liquids inside it to separate. Alternative methods use the different surface properties of coal and waste. In froth flotation, coal particles are removed in a froth produced by blowing air into a water bath containing chemical reagents. The bubbles attract the coal but not the waste and are skimmed off to recover the coal fines. Recent technological developments have helped increase the recovery of ultrafine coal material.

Coal Transportation

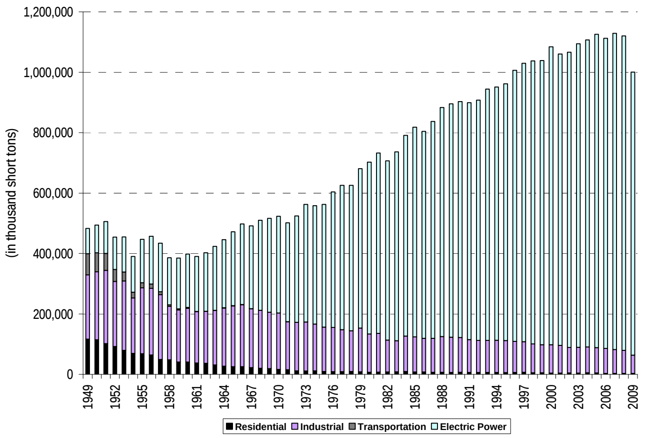
The method of transporting coal depends on the distance and geography between the mine and the customer. Coal is generally transported by conveyor or truck over short distances. Trains and barges are used for longer distances within domestic markets, or alternatively coal can be mixed with water to form coal slurry and transported through a pipeline. Ships are commonly used for international transportation, in sizes ranging from Handymax (40,000-60,000 DWT), Panamax (about 60,000-80,000 DWT) to large Capesize vessels (80,000-plus DWT). About 941 million tons of coal was traded internationally in 2009. This represents only 16% of global consumption, as most coal is used in the country in which it is produced. Coal transportation can be very expensive, in some instances accounting for up to 70% of the delivered cost of coal.

The U.S. Coal Market

Electric utilities are by far the dominant consumer of U.S. coal, with the electric power sector accounting for 94% (936.5 million tons) of total coal consumption in 2009. The remaining 6% is consumed primarily by the industrial sector either in the form of thermal coal for dedicated electricity generation at private industrial facilities (approximately 4%), or coking coal used in the production of steel (approximately 2% of total consumption).

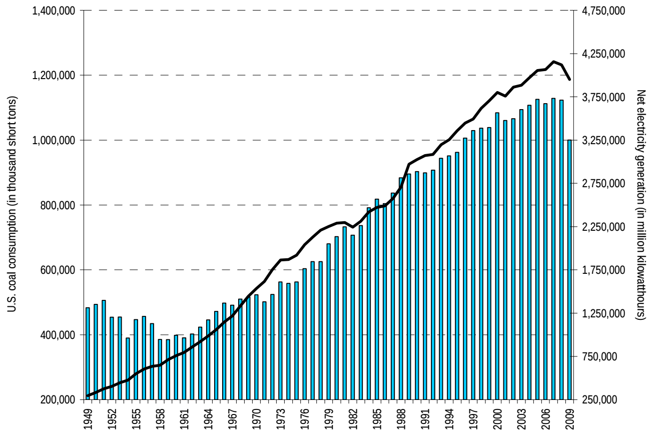
Given the dominant role of electricity generation in absorbing coal output in the United States, it is not surprising that there is a relatively high correlation between coal demand in the United States and overall U.S. electricity consumption.

Exhibit 119: U.S. Coal Consumption by End Use, (1949–2009)



Source: EIA, Credit Suisse estimates.

Exhibit 120: U.S. Coal Demand and Electricity Generation, (1968–2009)

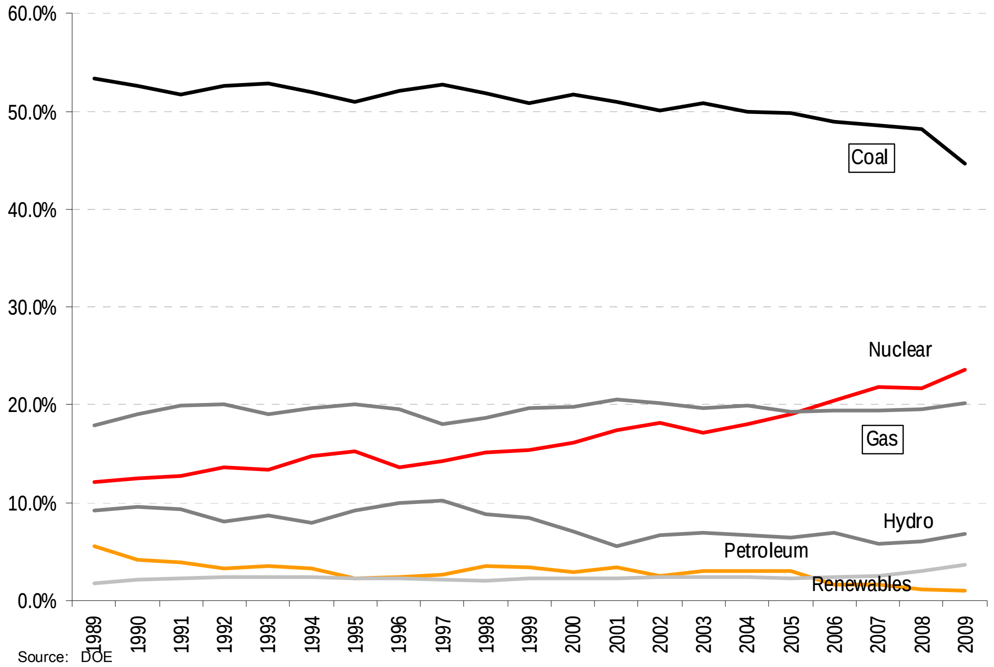


Source: EIA, Credit Suisse estimates.

Market Share among Fuel Sources

During the past decade, coal's portion of total electricity generation in the United States has declined slightly, to 44.7% in 2009 from 50.9% in 1999. Meanwhile, much attention has been given to the growth of natural gas in the electricity generation market. While natural gas has gained market share during the past decade (to 23.6% in 2009 from 15.4% in 1999), coal remains the dominant fuel source.

Exhibit 121: Electricity Generation Fuel Market Share

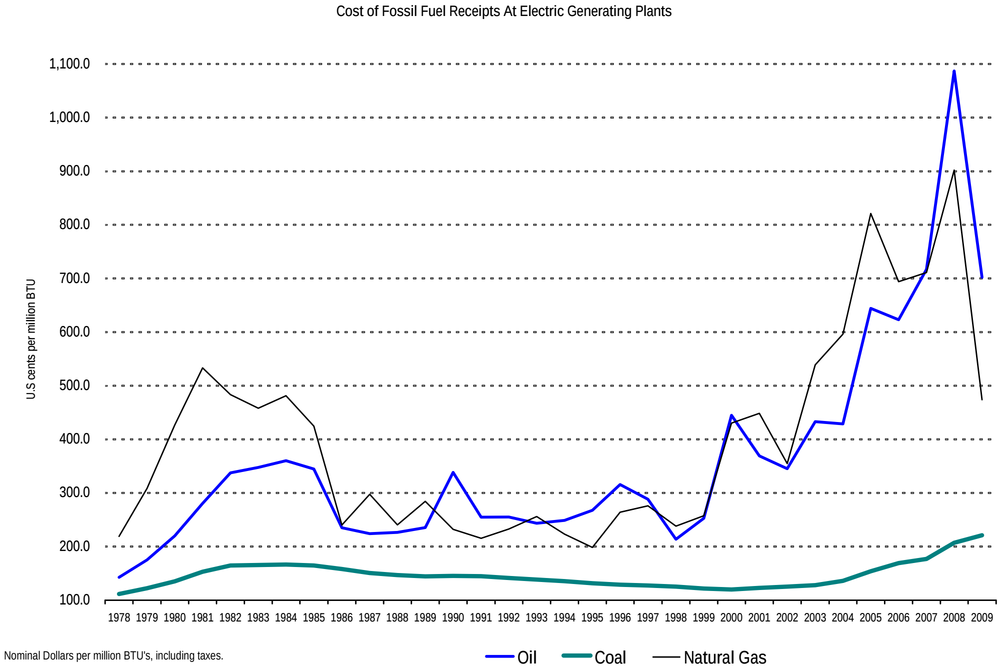


Source: Department of Energy.

As such, just as the coal industry is highly dependant on one customer (the electric utilities), arguably the electric utilities are also dependent on the coal industry, given coal's position as the primary fuel source for electricity generation.

Among the major fossil fuels, coal is the least expensive fuel source on an all-in cost basis to electric utilities.

Exhibit 122: Average Cost in Dollars per Million BTU (1978–2009)

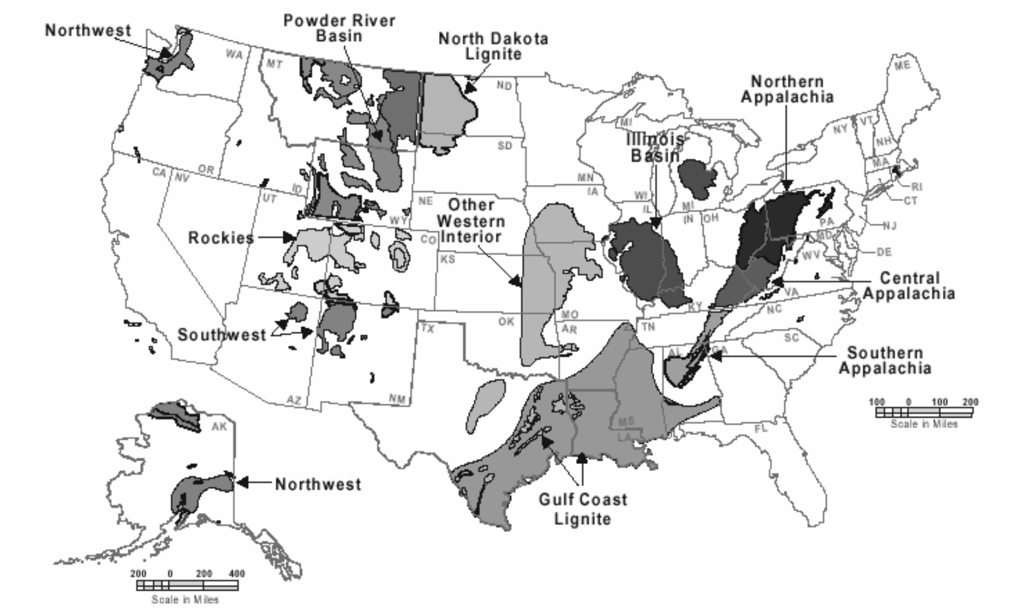


Source: Company data, Credit Suisse estimates.

U.S. Regional Coal Supply Patterns

According to the Energy Information Administration, there are 11 major coal supply regions in the United States, with the Powder River Basin, Central Appalachia region, and Northern Appalachia region accounting for a combined 72% of total U.S. coal production in 2009.

Exhibit 123: **U.S. Coal Supply Regions**



Source: EIA, Credit Suisse estimates.

Exhibit 124: **Top Ten Coal Producers in the United States (2009)**

Rank	Company Name	Production (Thousand Short Tons)	Percentage of Total Production
1	Peabody Energy Corporation	189,232	17.6%
2	Arch Coal Inc.	148,061	13.8%
3	Cloud Peak Energy	90,965	8.5%
4	Alpha Natural Resources LLC	83,523	7.8%
5	CONSOL Energy Inc.	58,145	5.4%
6	Massey Energy Co.	37,161	3.5%
7	NACCO Industries Inc.	31,085	2.9%
8	Patriot Coal Corp.	29,268	2.7%
9	Peter Kiewit Sons Inc.	27,136	2.5%
10	Alliance Resource Operating Partners LP	25,874	2.4%
	Total		**67.1%**

Source: EIA.

Powder River Basin

The Powder River Basin (PRB), located primarily in Wyoming (but with seams extending into Montana) is the single largest coal-producing region in the United States (by volume) and has been the fastest growing coal-producing region during the past decade.

The primary coal type from this region is subbituminous, which typically has a relatively low heating value (in the range of 8,500-8,900 Btu per pound), but is also among the cleanest coal types (with a sulfur content of 0.3-0.5 pounds of sulfur per million Btu). Given this low sulfur characteristic, PRB coal generally enjoys a competitive advantage over coal produced from other regions in terms of meeting federal emission standards. However, offsetting this advantage is lower heat content, coupled with the relatively greater cost of transporting PRB coal across the country to the large utilities in the Midwest and the East. The cost of transporting coal from the mine to the power plant is paid by the utility. As a result, PRB coal is generally priced significantly below coal from other regions. For example, 8,800 Btu PRB coal currently sells on the spot market for $14-15 per ton, compared with the current spot price of $70-75 per ton for 12,500 Btu Central Appalachia coal.

Production costs are also significantly lower in the PRB when compared with other regions. Most operations are large, surface operations, as opposed to the generally smaller, underground operations in the East. As such, all ten of the largest coal mines in the United States in 2007 (when measured by production volume) were located in the PRB region, with each of these coal mines operating as surface operations. To put the cost differential in perspective, in 2009 Arch Coal reported average production costs in the PRB of $11.43 per ton, while the company reported production costs from Central Appalachia of $55.39 per ton.

The growth in demand for PRB coal is primarily owing to the onset of Phase II of the Clean Air Act, which tightened the allowable emission standards for utilities and accordingly shifted the utility customer's focus away from heat content and toward low-sulfur coals. At the same time, in an effort to capture market share, it appears that PRB producers were willing to sacrifice some potential pricing power in exchange for market share gains relative to their Eastern competitors.

Exhibit 125: **Ten Largest Coal Mines in the United States (2009)**

Rank	Mine Names/Company	Mine Type	State	Production (short tons)	Percentage of U.S. Production
1	North Antelope Rochelle Mine/Peabody Energy	Surface	Wyoming	98,279,377	9.1%
2	Black Thunder/Arch Coal	Surface	Wyoming	81,079,043	7.5%
3	Cordero Mine/ Cloud Peak Energy	Surface	Wyoming	39,380,964	3.7%
5	Antelope Coal Mine/ Cloud Peak Energy	Surface	Wyoming	33,975,524	3.2%
5	Jacobs Ranch Mine/Arch Coal	Surface	Wyoming	29,021,485	2.7%
6	Belle Ayr Mine/Alpha Natural Resources	Surface	Wyoming	28,395,952	2.6%
7	Buckskin Mine/Kiewit Mining Group	Surface	Wyoming	25,411,798	2.4%
8	Caballo Mine/Peabody Energy	Surface	Wyoming	23,252,475	2.2%
9	Eagle Butte Mine/Alpha Natural Resources	Surface	Wyoming	21,479,183	2.0%
10	Spring Creek Mine/Cloud Peak Energy	Surface	Montana	17,608,969	1.6%
	Total				**37.0%**

Source: EIA.

Central Appalachia

The Central Appalachian region, comprising roughly Virginia, the eastern portion of Kentucky, and the southern portion of West Virginia, is the nation's primary source of bituminous coal that is relatively low in sulfur. The heat content of Central Appalachia coal is significantly higher than that of Wyoming coal, with heating values averaging approximately 12,500 Btu per pound. Sulfur content is moderately higher than that of PRB coal, with an average sulfur content of approximately 0.8-1.2 pounds per million Btu. Given the high heat characteristic, coupled with the relatively low sulfur content and the proximity to the Southeastern United States, Central Appalachia coals often find their primary customer in the form of Southeastern- and Mid-Atlantic-based utilities. In addition, the Central Appalachia region also holds the largest reserves of metallurgical-grade coal, which is often sold at a premium into the seaborne coking coal market for use in the production of steel.

Northern Appalachia

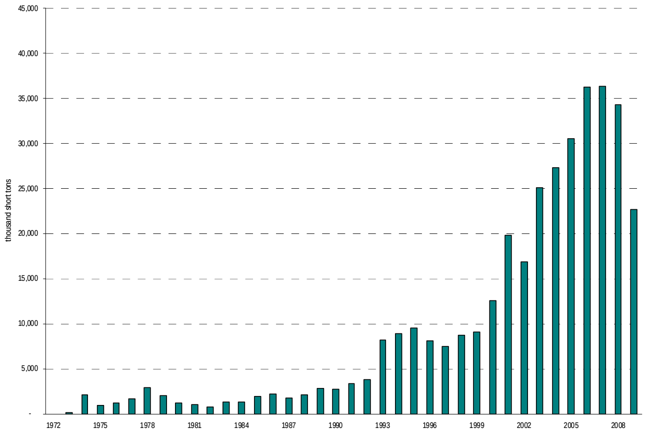
Coal from Northern Appalachia (Maryland, Ohio, northern West Virginia, and the bituminous coal regions of Pennsylvania) have a relatively high sulfur content, ranging from 1.4 to 3.5 pounds of sulfur per million Btu, with heating values in the range of 11,000 to 13,000 Btu per pound. In general, coals from the Northern Appalachia region enjoy the competitive advantage of lower transportation costs relative to other regions owing to this region's close proximity to the high concentration of coal-fired power plants in the Northeast and Midwest (many of which are equipped with emissions control equipment to mitigate sulfur dioxide and other particulate emissions). The key driver of demand for this region is the significant onset of scrubber installations over the next decade, which will increase demand for higher-sulfur coals.

Most production from Northern Appalachia comes from underground mining operations. Many coal seams in Northern Appalachia have proven to be conducive to longwall mining, which is generally less expensive and more productive from an operating perspective when compared with other traditional forms of underground mining techniques. The expansion of longwall mining in Northern Appalachia during the 1990s essentially served to increase productivity and reduce operating costs in the region.

U.S. Imports and Exports

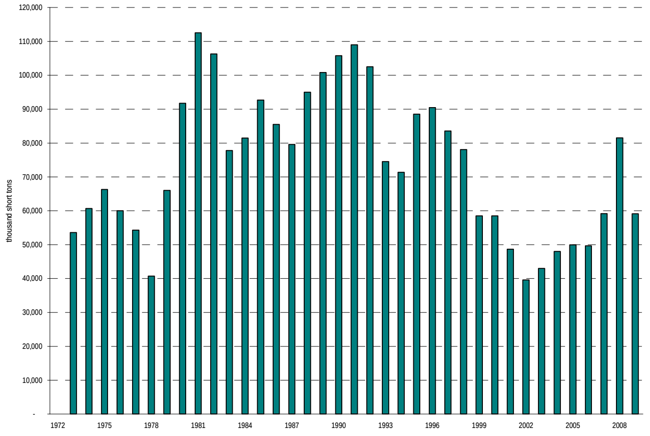
The U.S. coal market is approximately 1.1 billion tons annually, of which imports and exports are a relatively small portion. In 2009, imports of coal represented approximately 2% of total consumption, while the United States exported about 5.5% of its total production for the year. While imports have grown significantly over the past decade to 22.6 million tons in 2009 from about 9 million tons in 1999, as demonstrated in Exhibit 126, they are still below peak level imports reached in 2006-07. The level of exports from the United States has stayed relatively the same over the past decade at around 59 million tons, and is still well below some of the peak levels seen in the late 1980s and early 1990s.

Exhibit 126: U.S. Coal Imports, 1972–2009



Source: EIA, US ITC.

Exhibit 127: U.S. Coal Exports, 1972–2009



Source: EIA, US ITC.

Seaborne Coking Coal

Coking coal (metallurgical coal) is a less abundant material relative to others, with high-quality deposits found primarily in western Canada, the eastern United States, and Australia. Metallurgical coal is primarily used for the production of steel, whereby 70% of global steel production is based on the smelting of iron ore in blast furnaces and the subsequent refining of the iron into steel, mainly in Basic Oxygen Furnaces (BOF). A blast furnace typically uses iron ore, coke (made from metallurgical coal), small quantities of limestone, and, where Pulverized Coal Injection (PCI) is employed, pulverized or granulated thermal coal. At present, the BOF method accounts for the bulk of global steel production processes, while the Electric Arc Furnace (EAF) method accounts for the remainder (approximately 30%). The EAF method has represented the fastest growing segment of steel production technology, increasing market share to its current level from approximately 10% over the past few decades.

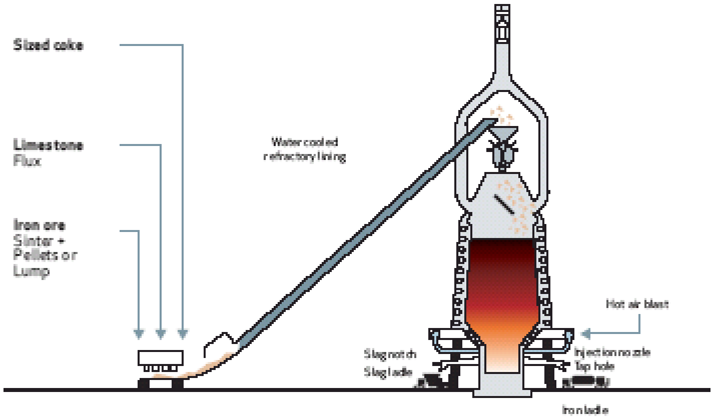
Metallurgical coal is used as a source of carbon for converting a metal ore (usually an oxide of the metal) to the metal itself. This process, usually described as smelting, involves removing the oxygen in the ore by forcing it to combine with the carbon in the coal to form CO_2. This involves burning the coal, which supplies the necessary heat to reduce the ore, and also to melt the resultant metal, helping to separate it from any slag produced in the process.

Properties and Uses

Coke is made from coking coals, which have certain physical properties that cause them to soften, liquefy, and then resolidify into hard but porous lumps when heated in the absence of air. Coking coals must also have low sulphuric and phosphorous content.

Metallurgical coal is carbonized in batteries of coke ovens. The coal blend, crushed to a maximum size of 3 mm, is poured into the top of the ovens and heated to above 1,200°C over a period of 18-20 hours. The volatile contents of the coal are driven off as coke oven gas. The red-hot coke is pushed out of the ovens, cooled, and screened to remove the smaller sizes. The larger-sized material (typically above 30 mm) goes to the blast furnace.

Exhibit 128: **Basic Oxygen Furnaces (BOF)**



Source: World Coal Institute.

Ore, coke, and limestone are fed into the top of the furnace. The hot air blast and, if PCI is installed, the pulverized coal, are injected through nozzles into the base of the furnace. The pulverized coal injected in this way is used as a less expensive source of carbon and fuel. The molten iron or hot metal are periodically tapped from the bottom of the furnace and taken directly to the BOF. Steel scrap and more limestone are added, and oxygen is blown onto the liquid metal, which is 93-95% pure iron at this stage. The reaction with the oxygen raises the temperature to 1,600-1,650°C and oxidizes the impurities to leave almost pure liquid steel.

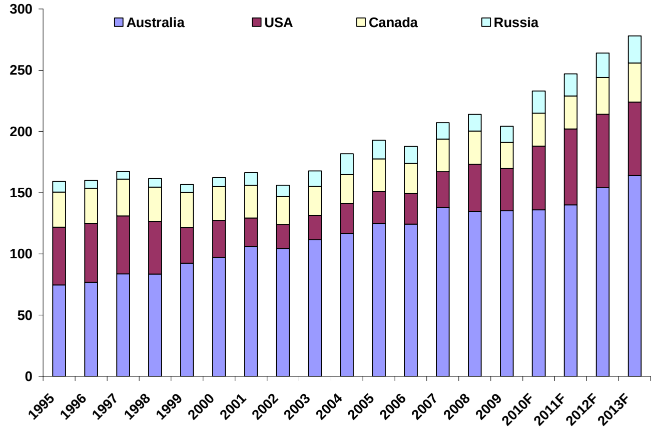
Iron ore, mined in many countries, is mineral containing iron oxides. Commercial ore grades usually have an iron or ferrous content of at least 58%. Most of the ore fed to the furnace is finely ground and then mixed and heated with coke fines to form sinter. Smaller quantities of natural lump or pellet ores are then added.

Blast furnaces with PCI require 350-400 kg of coke, made from 525-600 kg of coking coal, plus 100-200 kg of cheaper PCI coal (around 700 kg of coal for each tonne of hot metal produced). Furnaces without PCI use more coke, also equivalent to some 700 kg of coal, but all of it the more expensive coking coal. As each tonne of steel uses approximately 90% hot metal and 10% scrap, about 630 kg of coal is used per tonne of steel.

Global Coking Coal Supply

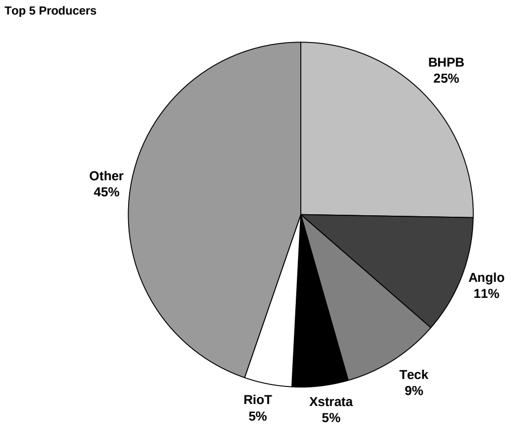
The supply of internationally traded coking coal is dominated by three countries: Australia, the United States, and Canada. Combined, these three countries accounted for approximately 80% of the global traded coking coal supply in 2010.

Exhibit 129: Top Four Exporting Countries of Coking Coal



Source: AME, Credit Suisse estimates.

Exhibit 130: Top Five Exporters of Coking Coal



Source: AME, Credit Suisse estimates.

Shiploading and Blending

With the majority of Australian and Canadian metallurgical coals exported, efficient coal loading at major ports is extremely important. Loading facilities are important buffer storage areas between discharge from road/rail and loading onto outbound ships that can blend different coals to produce specific compositions required by customers.

Most of the coal produced at major exporting countries arrives by rail and is unloaded from railcars into hoppers underneath the track. Each railcar is fitted with automatic discharge doors that are triggered to discharge the payload of coal. From the hoppers, the coal is either loaded directly onto the ship or taken by conveyor to a nearby stockpile.

The system can also be used to blend coal as it is received, where different types of coal are laid in predetermined patterns by stackers in a way that produces the required blends to fine tolerances when reclaimed. The process is made more complex by the fact that the types of coal required for blending may arrive at different times in varying sequences, and the plant is therefore carefully controlled to ensure a high degree of efficiency.

Exhibit 131: Japan-Australia JFY FOB Contract Prices (US$/T, Nominal Terms)

Japan-Australia JFY FOB contract prices (US$/t, nominal terms)

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Premium Hard-Coking Coal	48	46	58	127	114	98	305	125	201
Semi-Soft Coking Coal	34	30	43	80	58	64	240	80	144
Low Volatile PCI	33	33	47	102	66	68	245	85	149
Premium Hard-Coking Coal	*13%*	*-4%*	*25%*	*119%*	*-10%*	*-14%*	*211%*	*-59%*	*61%*
Semi-Soft Coking Coal	*-9%*	*-10%*	*43%*	*85%*	*-27%*	*10%*	*276%*	*-67%*	*80%*
Low Volatile PCI	*0%*	*1%*	*42%*	*119%*	*-35%*	*2%*	*263%*	*-65%*	*75%*

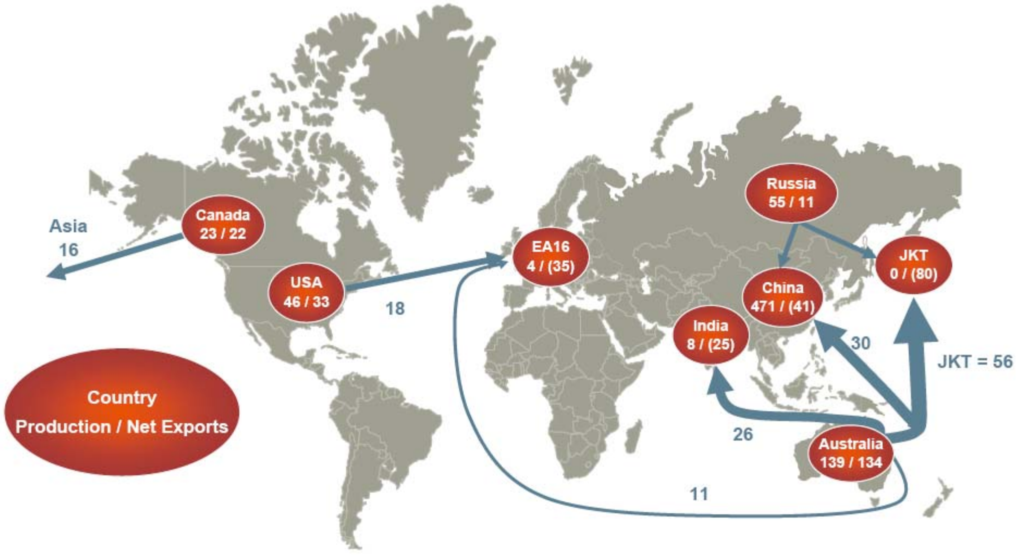
Source: Company data, Credit Suisse estimates.

Coal is traded all over the world, with coal shipped huge distances by sea to reach end markets. Over the past twenty years, seaborne coking coal trade has increased on average 1.6% per year. Overall seaborne trade in coal reached 941Mt in 2009; while this is a significant amount of coal, it still only accounts for about 16% of total coal consumed. Most coal is used in the country in which it is produced.

Transportation costs account for a large share of the total delivered price of coal; therefore, seaborne trade in coal is effectively divided into two regional markets: the Atlantic market, made up of importing countries in Western Europe, notably the United Kingdom, Germany, and Spain; and the Pacific market, which consists of developing and OECD Asian importers, notably Japan, Korea, and Chinese Taipei. The Pacific market currently accounts for about 57% of world seaborne coal trade.

Australia is the world's largest supplier of coking coal, accounting for 54% of world exports. The United States and Canada are significant exporters, and Indonesia is emerging as an important supplier.

Exhibit 132: Global Coking Coal Suppliers



Source: Trade statistics and BHP Billiton estimates.
Note: Production and trade flow figures are in million tonnes per year. All data is for the year ended 2009. Location of the arrows are indicative.

Source: BHP Presentation.

Demand Drivers—Background

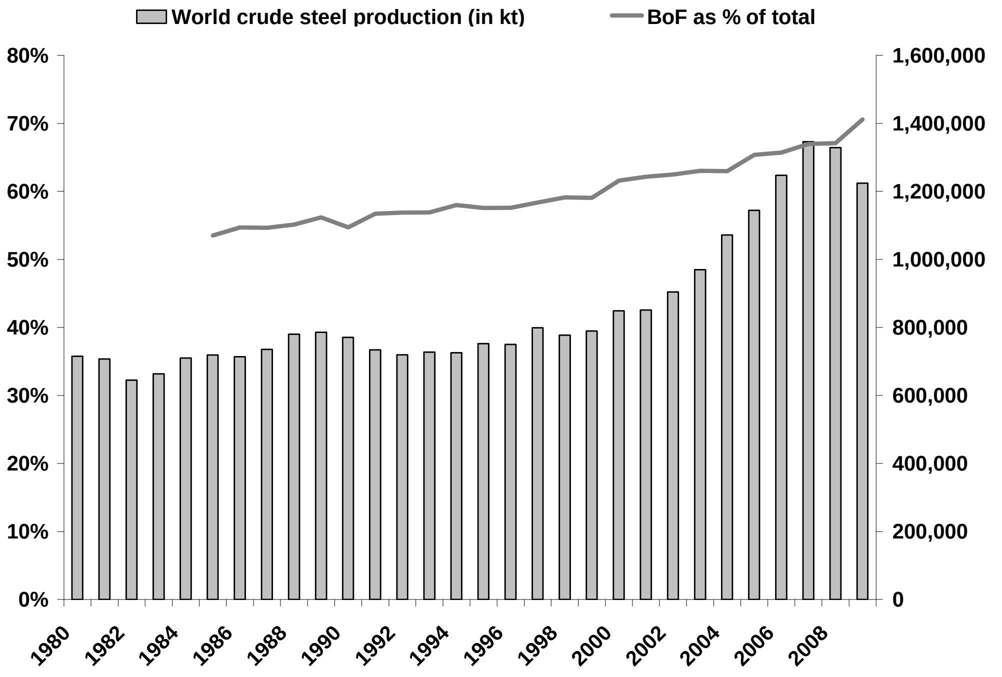
Metallurgical Coal demand

There are two different processes used for making steel:

1. Basic oxygen furnace method (BOF)
2. Electric arc furnace method (EAF)

BOFs use iron ore as the ferrous input for steel-making and consume metallurgical coal in the form of coke to produce the raw form of steel, pig iron. The generally smaller-scale EAFs use scrap as the ferrous input and rely on large amounts of electricity to remelt the scrap as its primary feedstock to produce steel.

Exhibit 133: **World Crude Steel Production (Kt)**



Source: Credit Suisse estimates.

Around 70% of global steel production is made by BOF, and therefore relies on inputs of coking coal.

Coking Coal

Coking coal is coal that can be used in the production of coke, which in turn is used in the blast furnace in the production of pig iron.

Coke is made by baking metallurgical coal in ovens at 1,650-2,000 degrees Fahrenheit. This process removes water and impurities in the coal in order to obtain an almost pure form of carbon that is lightweight but still structurally strong to avoid being crushed by the iron ore’s weight in the blast furnace. The coke also becomes more porous, which enables proper airflow in the cooking section.

Coking coals are able to be softened, liquified, and resolidified into hard and porous lumps when heated in the absence of air.

The exact amount of coking coal required to make a tonne of steel depends on the set-up and efficiency of the blast furnace; however, most BOFs use between 0.55 and 0.63t of coking coal per tonne of steel produced. (More details on the steel-making process can be found in the steel portion of the primer.)

Hard coking coal has the highest carbon content, which in turn has the highest BTU content, characteristics that are needed for the steel production process.

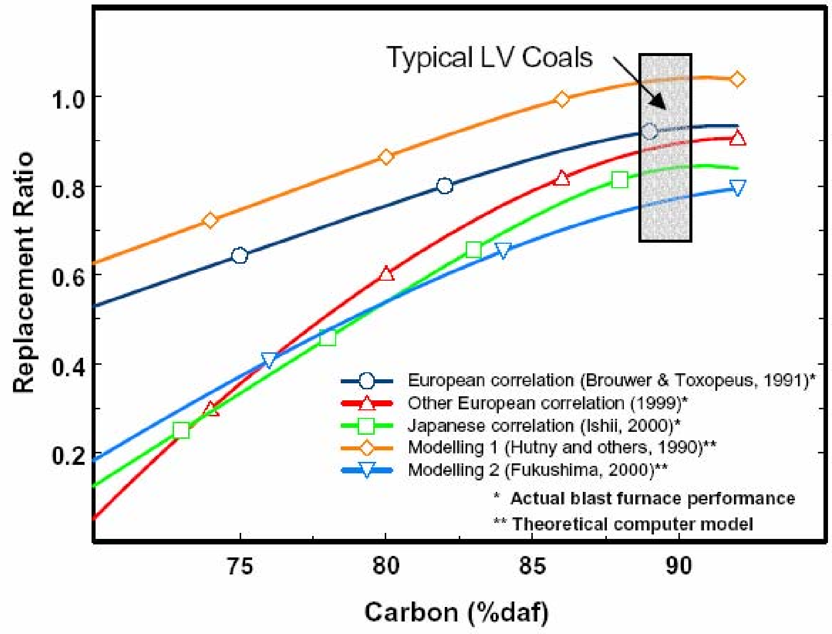
Type of Coal	Carbon content	Commonly known as
Peat	11%	-
Lignite	38%	Soft coal / brown coal
Bituminous	65%	Household coal
Anthracite	96%	Hard coal

Pulverised Coal Injection (PCI) Coal

In recent years, we have seen a trend toward using PCI coal in steel-making as a partial substitute for coking coal. PCI coal is crushed into a fine powder and injected into blast furnaces as a replacement for coke in the production of pig iron. The stimulus behind this trend has been the spread between PCI prices (which have historically traded at a slight premium to thermal coal) and coking coal.

The replacement ratio of PCI coal to coke varies depending on the carbon content of the material, as illustrated in **Exhibit 134**. However, for the purposes of doing a like-for-like comparison with coking coal prices, we assume that the substitution ratio is such that 1.0 tonne of low volatile PCI coal can replace 1.5 tonnes of more expensive coking coal (Macarthur Coal website).

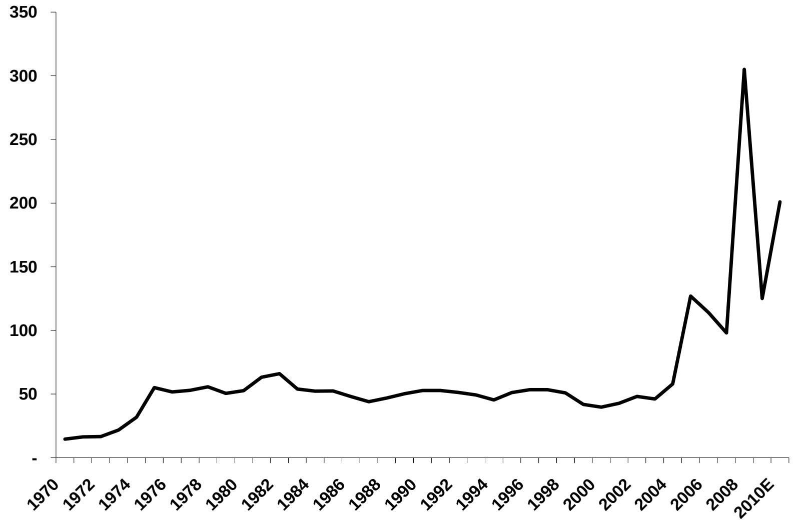
Exhibit 134: PCI Substitution Rates



Source: Jellinbah Resources.

Based on the PCI coal substitution ratio assumed above, we can take the data above one step further and compare actual HCC prices with a PCI coal equivalent substitution price. Approximately 1.3 tonnes of coking coal are required to make 1.0 tonne of coke for steel-making, and we estimate that the conversion cost associated with the process costs roughly $10 per tonne.

Exhibit 135: Spot Coke Prices (US$/T)



Source: AME, Credit Suisse estimates.

Toward the end of JFY 2010, we observe supply constraints of coking coal and hence coke, which resulted in increasing upward pressure on coking coal prices. Coking coal prices have been settling around $225/t for 1Q 2011, up 8% over 4Q 2010 prices of $209/t.

Exhibit 136: 4Q 2010 Coking Coal Settlement Prices—by Key Contract Brands

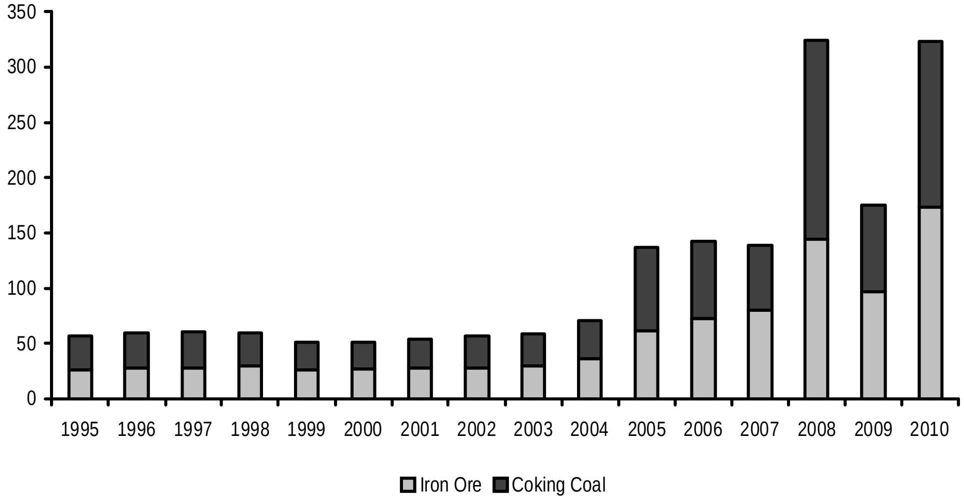
Producer	Brand	Q4 2010	CSR	VM	Ash	Sulfur	Phosporous	Fluidity	Dilation
BHPB Mitsubishi Alliance	Saraji	209	74	18.8	9.7	0.62	0.030	160	86
BHPB Mitsubishi Alliance	Peak Downs	209	74	20.7	9.7	0.60	0.035	400	102
Rio Tinto Coal Australia	Hail Creek	209	73	20.5	8.5	0.35	0.070	400	80
Teck Coal	Elkview	209	72	21.0	9.5	0.40	0.065	60	5
Anglo Coal Australia	German Creek	209	71	19.5	9.0	0.54	0.064	250	100
Xstrata Coal	Wollombi Coking	209	70	21.5	9.5		0.015	750	
Solid Energy	West Coast Premium	209	70	31.5	3.5	1.90	0.004	400	70
Xstrata Coal	Oaky North	209	67	24.0	9.0	0.70	0.060	2000	230
Xstrata Coal	Oaky Creek	209	62	26.0	9.0	0.80	0.060	6000	270
Solid Energy	Western Coking Coal	206	70	31.5	3.5	2.30	0.004	500	80
BHP Billiton Illawarra Coal	Illawarra	205	73	22.5	9.5	0.45	0.050	1200	91
BHPB Mitsubishi Alliance	Riverside	205	72	22.0	9.8	0.55	0.007	450	81
Teck Coal	Standard	205	72	23.5	9.5	0.50	0.700	150	35
Teck Coal	Premium	205	72	25.5	8.8	0.65	0.750	300	65
Peabody Energy Australia	North Goonyella	205	70	23.5	8.5	0.50	0.050	1000	100
Teck Coal	Eagle	205	70	27.5	8.0	0.70	0.700	600	105
BHPB Mitsubishi Alliance	Goonyella	205	68	24.3	8.9	0.52	0.025	1100	121
Rio Tinto Coal Australia	Hail Creek Higher Ash	205	66	20.5	10.5	0.40	0.080	200	45
Anglo Coal Australia	Moranbah North	205	65	24.5	8.5	0.50	0.030	1700	155
Vale	Carborough Downs	205	61	22.5	8.0	0.35	0.035	100	
Wesfarmers Resources	Curragh Hard	205	60	21.0	7.0	0.60	0.050	100	45
Jellinbah Resources	Lake Vermont Hard	205	60	21.6	7.0	0.44	0.070	120	30
Peabody Energy Australia	Metropolitan Hard	203	57	20.0	8.5	0.55	0.050	300	38
Mechel	K9	203	44	17.5	9.5	0.25	0.025		
Peabody Energy Australia	Burton Hard	202	50	22.9	8.0	0.50	0.055	250	31
BHPB Mitsubishi Alliance	Norwich Park	195	67	17.8	9.9	0.70	0.040	100	76
BHPB Mitsubishi Alliance	Gregory	190	60	33.5	6.8	0.70	0.035	7500	152
Rio Tinto Coal Australia	Kestrel	190	56	34.0	6.5	0.70	0.030	10000	153

Source: Platts, Credit Suisse estimates.

Implications of Coal to the Cost of Steel-Making

Generally, BOFs are used for making flat products, the commodity form of which is known as Hot Rolled Coil, or HRC. At $650/t, we estimate that coking coal represents roughly 35% of the total cost of steel making HRC, while iron ore is roughly the same to slightly lower at 30%.

Exhibit 137: Steel-Maker Cost—Iron Ore 62% Fe (1.6tonnes), Premium HCC (0.6 units FOB) US$/T



Source: AISI, Credit Suisse estimates.

Molybdenum

Periodic table symbol: Mo

Atomic number: 42

Molybdenum is an element used primarily as an alloy in the steel industry to enhance corrosion resistance, strength, high temperature durability, and hardness. Some molybdenum-containing chemicals are used in other industries, including lubricants, water treatment, and petroleum refining. In total, approximately 75% of molybdenum produced globally is used by the iron and steel industry.

Properties of Molybdenum

Strength and heat properties. Adding molybdenum as an alloy in steel-making increases the steel's strength, primarily owing to molybdenum's high heat resistance, as molybdenum melts at 4,730 degrees Fahrenheit (versus 2,730 degrees for crude steel).

Corrosion resistance. Molybdenum is highly resistant to weather, common atmospheric gases, and liquids. As such, molybdenum is frequently added to stainless steel for applications with corrosion-resistant requirements.

Primary Production Process

Molybdenum is typically found in the ore mineral molybdenite, but it is also found in the mineral wulfenite. The direct mining of molybdenum results in high–purity, chemical-grade molybdenum that is typically roasted and further processed into molybdenum chemicals products. Molybdenum is also frequently found as a byproduct of copper mining. The byproduct molybdenum is typically converted into molybdic oxide. Nearly 60% of the world's molybdenum is produced as a byproduct of copper mining. As such, molybdenum mining methods are similar to copper ore mining methods.

Types and Uses of Molybdenum

Steel-making. The most common use of molybdenum (accounting for almost 70% of consumption) is as an alloy in stainless and alloy steel. Molybdenum strengthens steel and makes it corrosion resistant. Because of its strength and ability to withstand high temperatures, molybdenum metal and alloys are common in a number of important products including lamp filaments, glass-melting electrodes, and electronic devices.

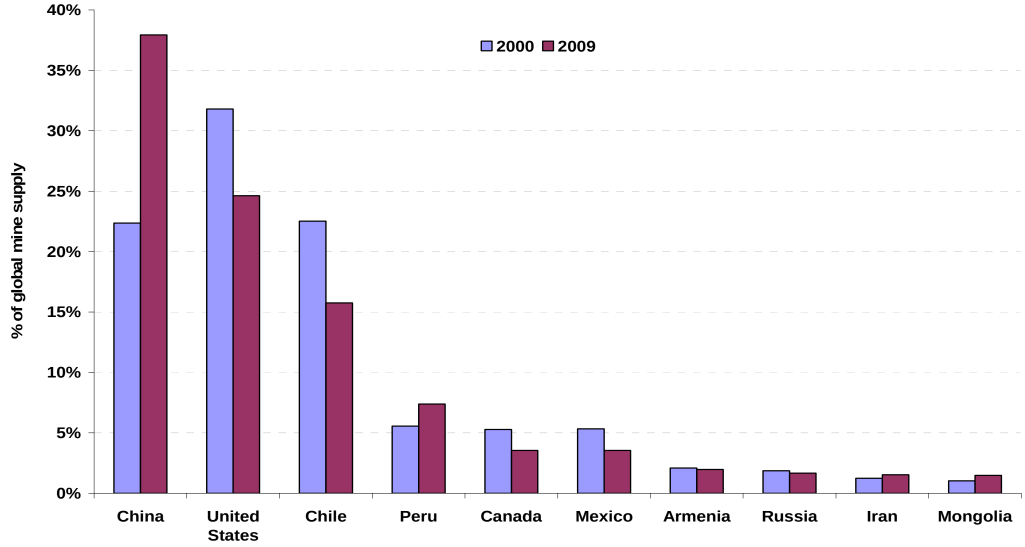
Molybdenum chemical products. These are used for purposes such as removing sulfur from crude oil, which results in cleaner-burning fuels and cleaner air. Increasingly stringent requirements for low-sulfur fuel oils make this application a particularly important use for molybdenum. Its high melting point also results in its use for smoke and flame retardants.

Molysulfide. As a solid lubricant, molybdenum helps reduce wear and friction and can sustain its durability in tough operating conditions, such as in car brakes. Molysulfide is also widely used in solvents and bonded coatings and is seeing increased use as an antiwear and extreme-pressure additive in lubricating oils and greases.

Substitutability. While molybdenum has potential substitutes, including vanadium, chromium, columbium, and boron, its substitutability is generally low, given the relatively large amount of reserves available (roughly 8.7 million tonnes globally) and its versatility in applications.

Global Mine Supply

Exhibit 138: Global Mine Supply (by Country)

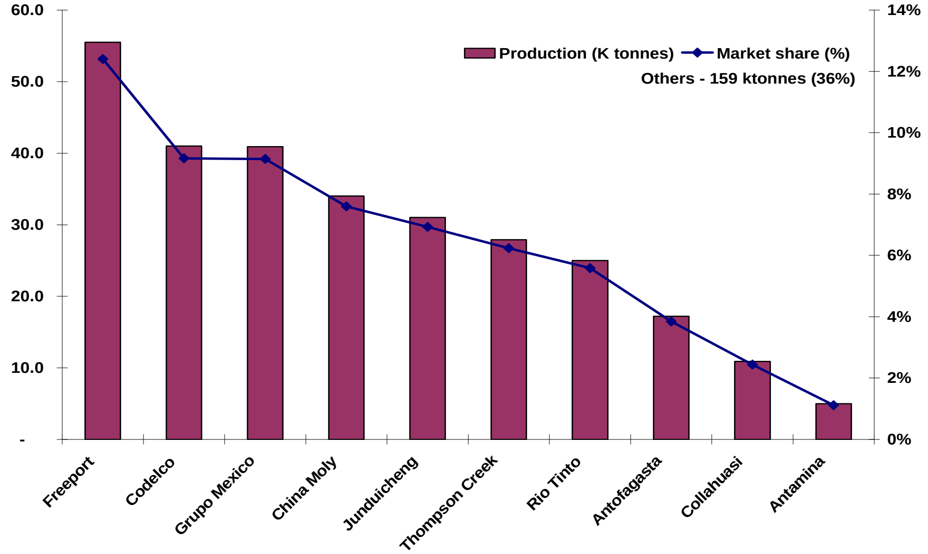


Source: USGS.

60% of global supply is produced as a byproduct of copper mining

Molybdenum mine production is highly concentrated, with China, the United States, and Chile accounting for approximately 78% of the world's molybdenum mine supply, with the top five countries accounting for more than 89% of total mine production in 2009. Since approximately 60% of the world's molybdenum supply is produced as a byproduct of copper mining, it is not surprising that some of the world's largest copper miners (Codelco, Freeport McMoRan, and Grupo Mexico) are also the world's three largest producers of molybdenum, accounting for roughly one-third of global supply in 2009.

Exhibit 139: Global Molybdenum Producers by Production and Market Share



Source: TCM presentation, Company reports, Credit Suisse estimates.

According to the United States Geological Survey (USGS), China has the world's largest molybdenum reserves, at 38% of the world's total reserves, followed by the United States at 31% and Chile at 13%. Combined, these countries hold 82% of the world's reserves.

Exhibit 140: World Molybdenum Reserves by Country (in 000s tonnes)

Country	Reserves	% of Total
China	3,300	38%
United States	2,700	31%
Chile	1,100	13%
Canada	450	5%
Russia	240	3%
Armenia	200	2%
Peru	140	2%
Mexico	135	2%
Kazakhstan	130	1%
Kyrgyzstan	100	1%
Mongolia	100	1%
Uzbekistan	60	1%
Iran	50	1%
World total	**8,705**	**100%**

Source: USGS.

Reserves refer to material that is economically viable at the time of determination; January 2010.

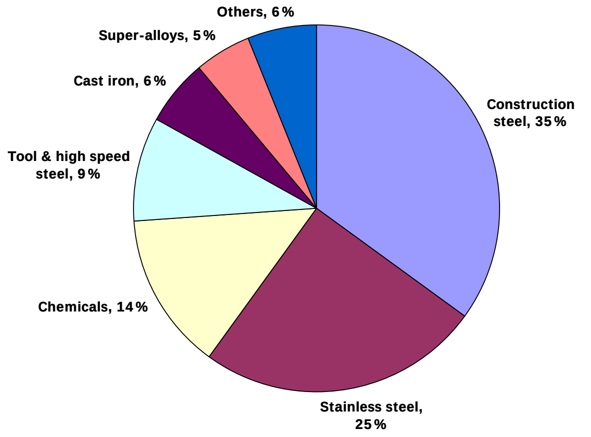
Global Demand

The main use of molybdenum is in stainless steel and alloy steel, accounting for about 75% of consumption. Specific steel applications use varying molybdenum loadings, with energy-related industries increasingly turning to the anticorrosive properties of molybdenum for pipeline construction, nuclear power plants, shipbuilding, desalination plants, and power generation plants, particularly in applications where resistance to extreme temperatures and pressure is required. This is also leading to structural changes in steel development itself. Higher nickel prices over the past several years have resulted in increased pressure to minimize nickel in certain steel applications, resulting in higher molybdenum usage. Molybdenum itself is relatively insulated from substitution, as the qualitative value of molybdenum to steels generally exceeds the cost of the raw material.

The main use of molybdenum is in stainless steel and alloy steel

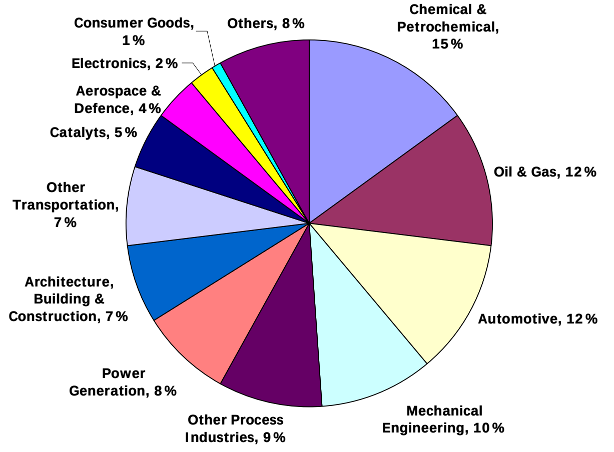
The global energy sector will continue to be a significant driver for molybdenum in the future. As oil reserves become remote, deeper drilling is required, leading to longer pipelines and better performance requirements of the steel used.

Exhibit 141: Molybdenum Consumption by First Use



Source: IMOA.

Exhibit 142: Molybdenum Consumption by End Use

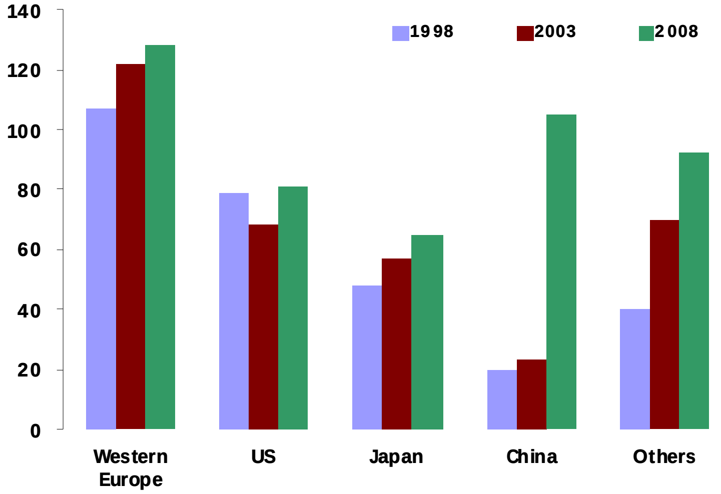


Source: IMOA.

The emerging nuclear fuel industry will provide emerging opportunities for molybdenum use. According to the World Nuclear Association (WNA), there are 441 reactors operating globally, generating 376,263 megawatts (MW) of electricity. Another 63 are under construction, with 474 planned or proposed (157 of which are in China). Molybdenum is used in various components such as steam generators, turbines, and coolant pipes. Such rapid expansion will create strong demand for molybdenum--bearing alloys.

Much like global production of molybdenum, the importance of China with regard to global supply of the metal has continued to increase over the past decade. (See Exhibit 143.)

Exhibit 143: Molybdenum Consumption by Region (Mlb)



Source: IMOA, Credit Suisse estimates.

Uranium

Periodic table symbol: U

Atomic number: 92

In its pure form, uranium is a silvery white metal of very high density, even more dense than lead. Uranium can take many chemical forms, but is generally found in its natural form as an oxide. Triuranium octoxide (U3O8) is the most stable form of uranium oxide and is the form most commonly found in nature. Uranium is one of the most abundant elements found in the earth's crust. It can be found almost everywhere in soil and rock, and in rivers and oceans. Traces of uranium are even found in food and human tissue. However, concentrated uranium ores are found in just a few places, usually in hard rock or sandstone.

Uranium in its naturally occurring form consists primarily of two isotopes, with the same chemical characteristics, but different atomic weights owing to the differing number of neutrons in their nuclei. The lighter isotope, U-235, contains only 0.7% of natural uranium, but it is the only isotope that can actually undergo fission and, thus, produce energy. The other isotope, U-238, accounts for the remaining 99.3% of natural uranium.

In order to be useful as fuel in the most prevalent nuclear power technologies, the percentage of U-235 must be increased to the level of 2-5% U-235, a process called enrichment. Enrichment is a technically difficult process, whose essence is highly secret because it is the same process used to produce some nuclear weapons material. (Nuclear weapons can be made from uranium of approximately 90% U-235.)

Uses

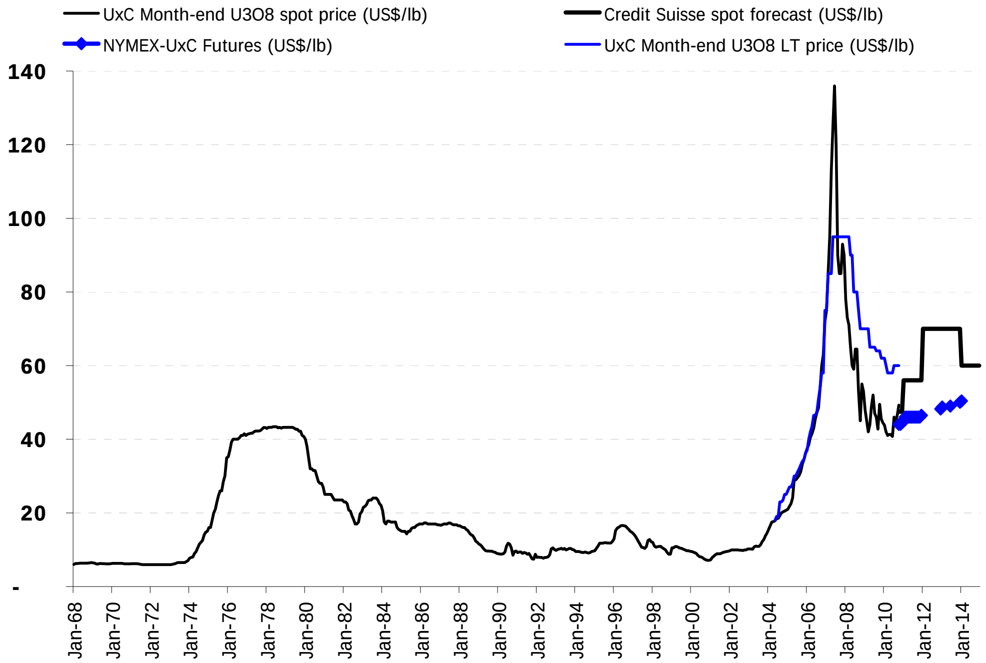
Early Uses

In the 1800s, the only use for uranium was to color glass and ceramics. Glassmakers used uranium to produce a yellow-green color. Ceramic glazes, ranging from orange to bright red, were used on household crockery and architectural decorations. Another radioactive element, produced in minute quantities from the decay of uranium, is radium. It was thought to have health-giving properties, and products containing radium, such as radioactive earth, went on sale. It was used in tonics and also in paint on clocks and watches to make them luminous.

Today's Uses

The use of uranium is virtually exclusive to fuel requirements in nuclear reactors for the generation of electricity. From the data on historical uranium prices we gathered, uranium prices follow three key trends. From the 1970s until the early 1980s, uranium prices were influenced by strong demand and low supply and averaged US$20-25 per lb in nominal terms. Major political changes in the mid-1980s culminated in the breakup of the Soviet Union and an end to the arms race. This led to a prolonged period of falling uranium prices, as nuclear disarmament treaties between the United States and the former Soviet Union resulted in considerable quantities of uranium (in the form of highly enriched uranium (HEU) being available to the market. From the early 1990s until 2001, uranium prices collapsed, averaging $8-10 per lb. Since 2001, uranium prices have been on the rebound, owing to increasing nuclear electricity generation capacity, increasing reactor fuel requirements, and falling inventories of uranium.

Exhibit 144: Historical Uranium (U3O8) Price



Source: Ux Weekly, Credit Suisse estimates.

More recently, uranium prices have become influenced by discretionary purchases (purchases not for immediate consumption). According to our estimates, discretionary purchases accounted for about 90% of 2010's spot volume, with almost 30% of the discretionary purchases attributable to investment and hedge funds.

Nuclear Electricity Generation

Electricity generation via nuclear power is an established and growing part of the global electricity mix and currently provides an estimated 16% of world electricity demand. By comparison, electricity generation by coal accounts for 40%, oil 10%, natural gas 15%, and hydro and other methods 19%. The support for nuclear power is greater in more mature economies of the world; the nuclear option accounts for 24% of electricity generated in OECD countries and 34% in the European Union.

Exhibit 145: Nuclear Electricity Generation

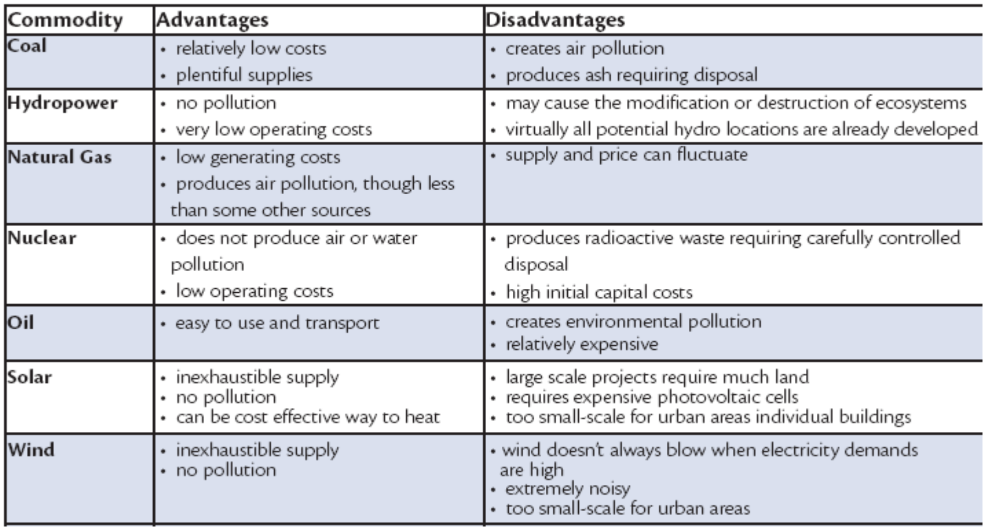
	NUCLEAR ELECTRICITY GENERATION 2009		REACTORS NOW OPERATING		REACTORS UNDER CONSTRUCTION		REACTORS CURRENTLY PLANNED		REACTORS PROPOSED	
	KWh (Billion)	**%**	**#**	**MWe**	**#**	**MWe**	**#**	**MWe**	**#**	**MWe**
Argentina	7.6	7.0	2	935	1	745	2	773	1	740
Armenia	2.3	45.0	1	376	-	-	1	1,060		
Bangladesh	-	-	-	-	-	-	-	-	2	2,000
Belarus	-	-	-	-	-	-	2	2,000	2	2,000
Belgium	45.0	51.7	7	5,943	-	-	-	-	-	-
Brazil	12.2	3.0	2	1,901	1	1,405	-	-	4	4,000
Bulgaria	14.2	35.9	2	1,906	-	-	2	1,900	-	-
Canada	85.3	14.8	18	12,679	2	1,600	4	4,400	3	3,800
China	65.7	1.9	13	10,234	23	25,900	39	44,270	120	120,000
Czech Republic	25.7	33.8	6	3,686	-	-	2	2,400	1	1,200
Egypt	-	-	-	-	-	-	1	1,000	1	1,000
Finland	22.6	32.9	4	2,721	1	1,650	-	-	2	3,000
France	391.7	75.2	58	63,236	1	1,650	1	1,630	1	1,630
Germany	127.7	26.1	17	20,339	-	-	-	-	-	-
Hungary	14.3	43.0	4	1,880	-	-	-	-	2	2,200
India	14.8	2.2	19	4,183	4	2,720	20	16,740	40	49,000
Indonesia	-	-	-	-	-	-	2	2,000	4	4,000
Iran	-	-	-	-	1	1,000	2	2,000	1	300
Israel	-	-	-	-	-	-	-	-	1	1,200
Italy	-	-	-	-	-	-	-	-	10	17,000
Japan	263.1	28.9	55	47,348	2	2,756	12	16,538	1	1,300
Jordan	-	-	-	-	-	-	1	1,000		
Kazakhstan	-	-	-	-	-	-	2	600	2	600
Korea DPR (North)	-	-	-	-	-	-	-	-	1	950
Korea RO (South)	141.1	34.8	20	17,716	6	7,000	6	8,400	-	-
Lithuania	10.0	76.2	-	-	-	-	-	-	1	1,700
Malaysia	-	-	-	-	-	-	-	-	1	1,200
Mexico	10.1	4.8	2	1,310	-	-	-	-	2	2,000
Netherlands	4.0	3.7	1	485	-	-	-	-	1	1,000
Pakistan	2.6	2.7	2	400	1	300	2	600	2	2,000
Poland	-	-	-	-	-	-	6	6,000	-	-
Romania	10.8	20.6	2	1,310	-	-	2	1,310	1	655
Russia	152.8	17.8	32	23,084	10	8,960	14	16,000	30	28,000
Slovakia	13.1	53.5	4	1,760	2	880	-	-	1	1,200
Slovenia	5.5	37.9	1	696	-	-	-	-	1	1,000
South Africa	11.6	4.8	2	1,800	-	-	-	-	15	2,000
Spain	50.6	17.5	8	7,448	-	-	-	-	-	-
Sweden	50.0	34.7	10	9,399	-	-	-	-	-	-
Switzerland	26.3	39.5	5	3,252	-	-	-	-	3	4,000
Thailand	-	-	-	-	-	-	2	2,000	4	4,000
Turkey	-	-	-	-	-	-	4	4,800	4	5,600
Ukraine	77.9	48.6	15	13,168	-	-	2	1,900	20	27,000
UAE	-	-	-	-	-	-	4	5,600	10	14,400
United Kingdom	62.9	17.9	19	10,962	-	-	4	6,680	9	12,000
USA	798.7	20.2	104	101,229	1	1,218	9	11,800	22	31,000
Vietnam	-	-	-	-	-	-	4	4,000	10	11,000
WORLD**	**2,560**	**14**	**441**	**376,313**	**58**	**60,484**	**152**	**167,401**	**337**	**382,825**

Source: WNA, Credit Suisse estimates.

According to the IAEA, the cost of nuclear power generation has been dropping over the past decade, owing partly to declining fuel costs (including enrichment), operating and maintenance costs, and lower financing costs. In general, the construction costs of nuclear power plants are significantly higher than those for coal- and gas-fired plants because of the need to use special materials and to incorporate sophisticated safety features and back-up control equipment. Together, these factors contribute much of the incremental cost of building a nuclear reactor.

The relative attractiveness of nuclear power becomes clearer when measured in the context of electricity-generation costs among competing commodities in the global electricity mix: oil, gas, uranium, and coal. It is in this respect that the relative usefulness of nuclear looks most interesting. Despite the substantial rise in the uranium price over the past year, the electricity-generating cost derived from nuclear power is not expected to rise significantly because of its relatively lower composition as part of the total generation cost of about 25%, compared with natural gas (about 91%), oil (about 88%), and coal (about 76%).

Exhibit 146: **Advantages and Disadvantages of Electricity Fuel Supply**



Commodity	Advantages	Disadvantages
Coal	• relatively low costs • plentiful supplies	• creates air pollution • produces ash requiring disposal
Hydropower	• no pollution • very low operating costs	• may cause the modification or destruction of ecosystems • virtually all potential hydro locations are already developed
Natural Gas	• low generating costs • produces air pollution, though less than some other sources	• supply and price can fluctuate
Nuclear	• does not produce air or water pollution • low operating costs	• produces radioactive waste requiring carefully controlled disposal • high initial capital costs
Oil	• easy to use and transport	• creates environmental pollution • relatively expensive
Solar	• inexhaustible supply • no pollution • can be cost effective way to heat	• large scale projects require much land • requires expensive photovoltaic cells • too small-scale for urban areas individual buildings
Wind	• inexhaustible supply • no pollution	• wind doesn't always blow when electricity demands are high • extremely noisy • too small-scale for urban areas

Source: WNA website.

Primary Production Process

The front end of the cycle from mine uranium to nuclear power is divided into the following steps: mining, milling, conversion, and enrichment.

Mining: How Is Uranium Mined?

Uranium ore is removed from the ground in one of three ways, depending on the characteristics of the deposit. Uranium deposits close to the surface can be recovered using the open pit mining method, and underground mining methods are used for deep deposits. In some circumstances, the ore may be mined by in situ leaching, a process that dissolves the uranium while still underground and then pumps a uranium-bearing solution to the surface.

Open Pit Mining

When uranium ore is found near the surface, generally less than 100 meters deep, it is typically extracted by the open pit mining method. Open pit mining begins by removing overburden (soil) and waste rock on top of the ore body to expose the hard rock. Then a pit is excavated to access the ore. The walls of the pit are mined in a series of benches to prevent them from collapsing. To mine each bench, holes are drilled into the rock and loaded with explosives, which are detonated to break up the rock. The resulting broken rock is then hauled to the surface in large trucks that carry up to 200 tonnes of material at a time.

Underground Mining

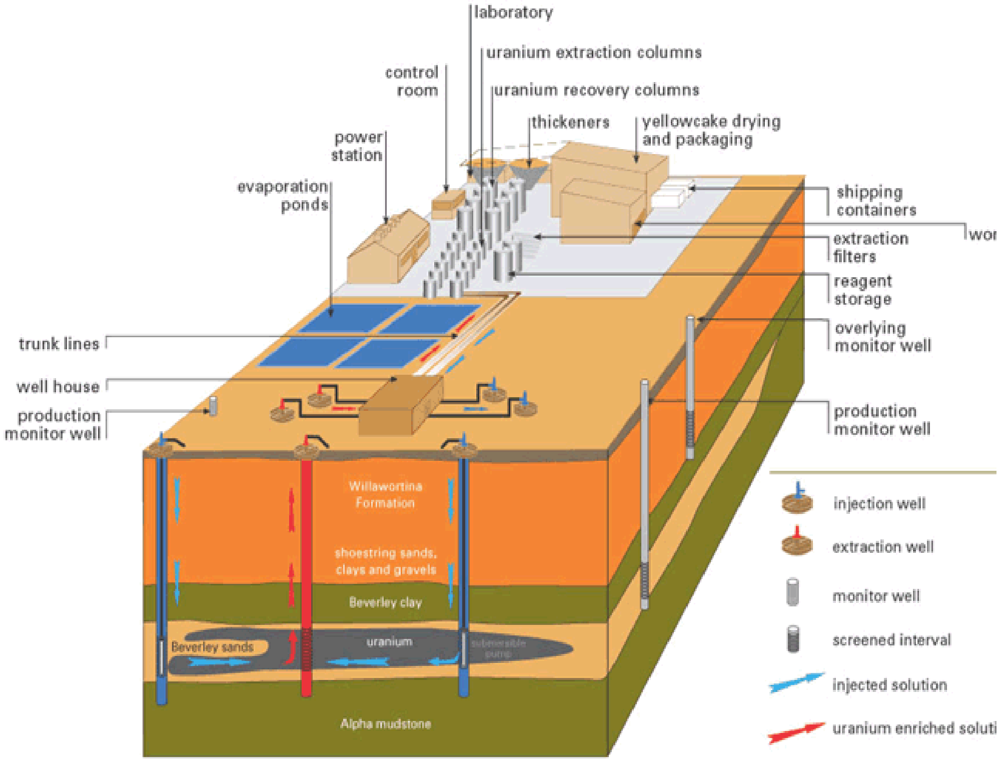
When an ore body is located more than 100 meters below the surface, underground mining methods are necessary, as it is uneconomic to mine by open pit. For example, Cameco Corporation's McArthur River ore body is located more than 500 meters below the surface, so it is mined using an underground mining method. The first step in underground mining is to access the ore. Entry into underground mines is gained by digging vertical shafts to the depth of the ore body. Then a number of tunnels are cut around the deposit. A series of horizontal tunnels, called drifts, offer access directly to the ore and provide ventilation pathways. All underground mines are ventilated, but in uranium mines, extra care is taken with ventilation to minimize the amount of radiation exposure and dust inhalation.

In most underground mines, the ore is blasted and hoisted to the surface for milling. At McArthur River, owing to the potential for radiation exposure from the high-grade ore, processing systems must ensure worker safety. As a result, the ore is processed underground to the consistency of fine sand, diluted with water, and pumped to the surface as slurry for milling.

In Situ Leach

In a few places, geological conditions allow uranium to be dissolved directly by pumping weak acid underground, bringing it back to the surface, and extracting the dissolved uranium. With this in situ leach (ISL) process, there is limited surface environmental disturbance. Leaching is another word for dissolving, and in situ means in the original position or place. The surrounding rock remains in place, while the dissolved uranium is pumped to the surface and then circulated through a processing plant for extraction.

Exhibit 147: **In Situ Leach Process**



Source: WNA Website.

Milling

At uranium mills, usually located near the mines, uranium-bearing ores are crushed and ground, and the uranium oxide is chemically extracted. The mill product, called uranium concentrates or yellowcake, is then marked and sold as pounds of U_3O_8 or kilograms of uranium content. Uranium can also be extracted as a byproduct of other mining operations, in association with gold, copper, or phosphate fertilizer.

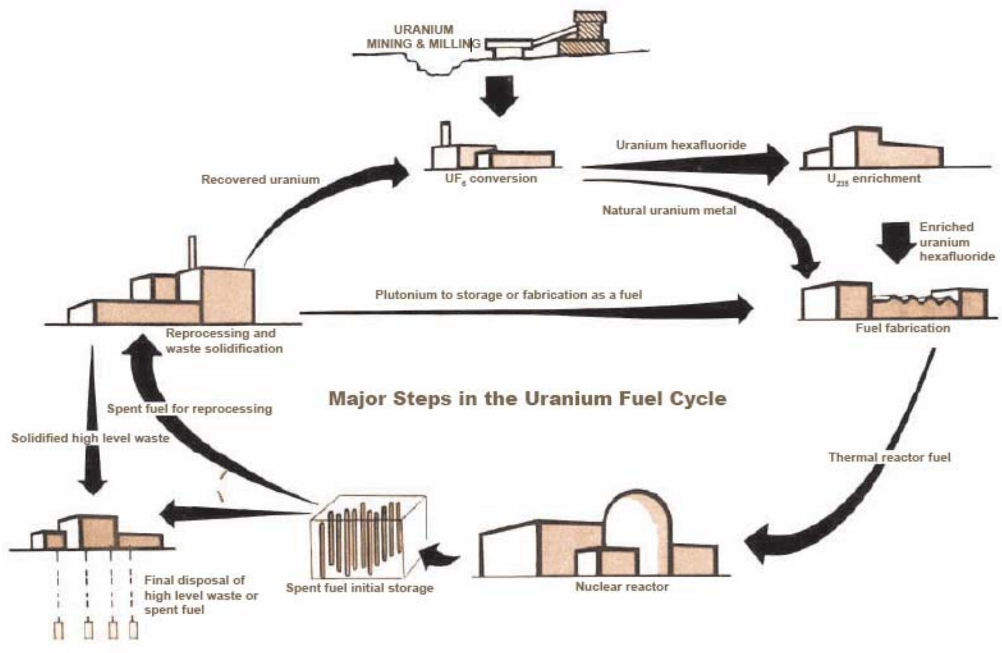
UF_6 Conversion

Next, the U_3O_8 is chemically converted to uranium hexafluoride (UF_6), which is a solid at room temperature but changes to a gas at slightly higher temperatures. This is a necessary feature for the next step, enrichment.

Enrichment

Natural uranium cannot be used as fuel because its content of fissile U-235 is too low at 0.7% to sustain a nuclear chain reaction. The process of uranium enrichment currently consists of two different technologies. The first (gaseous diffusion) consists of forcing UF_6 gas under pressure through a long series of barriers that pass U-235 at a slightly faster rate than the heavier U-238 atoms. This differential treatment progressively increases the percentage of U-235 in the product stream. Another enrichment technology (gaseous centrifuge) uses spinning centrifuges to separate the heavier U-238 atoms from the lighter U-235 atoms. It generally takes up to 20 stages to achieve the U-235 concentration needed for a nuclear reactor, but because of the small capacity of individual centrifuges, many are run in parallel. After enrichment, a product with 2.5-3.5% U-235 is obtained, with a typical plant producing enough fuel for about one hundred 1,000 MW nuclear power plants. Such plants are currently operating in Germany, Japan, and the United Kingdom.

Exhibit 148: The Nuclear Fuel Cycle

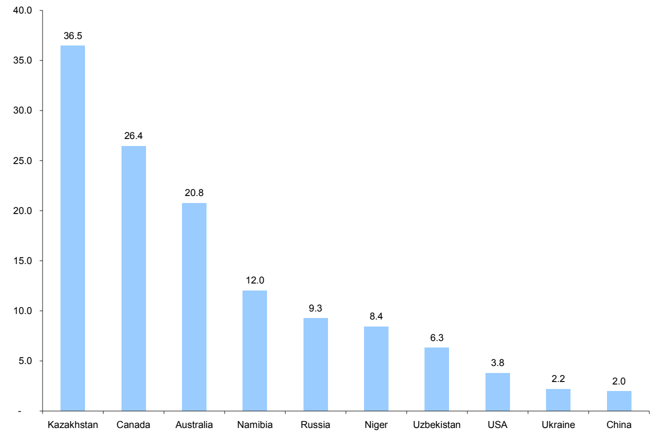

URANIUM MINING & MILLING
Uranium hexafluoride
Recovered uranium
UF_6 conversion
U_{235} enrichment
Natural uranium metal
Enriched uranium hexafluoride
Plutonium to storage or fabrication as a fuel
Fuel fabrication
Reprocessing and waste solidification
Major Steps in the Uranium Fuel Cycle
Spent fuel for reprocessing
Solidified high level waste
Thermal reactor fuel
Final disposal of high level waste or spent fuel
Spent fuel initial storage
Nuclear reactor

Source: Cameco Corp.

Global Mine Supply and Major Producers

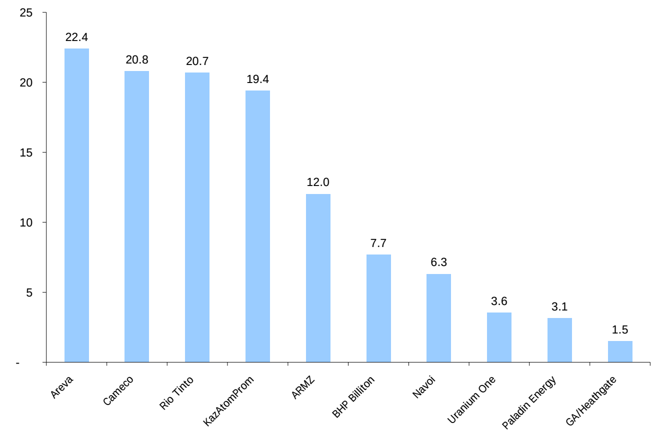
The uranium production industry is international in scope, with a small number of companies operating in relatively few countries. In 2009, five producers provided approximately 81% of the estimated world production of 117.6 million pounds of U_3O_8. On a country basis, Canada and Australia produced roughly 35% of the world's mined uranium production. Australia has the world's largest uranium reserves, totaling 28%, followed by Kazakhstan (20%) and Canada (12%). Despite this, Kazakhstan produces the largest share of uranium from mines (27% of world supply from mines), followed by Canada (20%) and Australia (16%). By our estimate, the top 10 uranium producing nations account for roughly 90% of global production.

Exhibit 149: Production by Country—2009



Source: World Nuclear Association, Credit Suisse estimates.

Exhibit 150: Production by Company—2009



Source: World Nuclear Association, Credit Suisse estimates.

New Global Mine Development

Cameco Corp. has been stating that they will double uranium production to 40Mln lbs of U_3O_8 by 2018. Most of the growth will come from Cigar Lake, which is expected to produce 18Mln lbs per year when running at full production. Expected production is slated for mid-2013.

In Australia, there are plans to triple the uranium output of Olympic Dam to about 42Mln lbs U_3O_8 per year. The proposal to the BHP board is expected at year-end 2011 for the $30Bln expansion go-ahead decision.

In Africa, mainly Niger and Namibia, growth initiatives are in place to make the region a contender as a powerhouse in the uranium space. Areva's Imouraren project in Niger is set to start producing in late 2012, ramping up to full production of 13Mln lbs. Areva also has the Trekkoppje project in Namibia that is expected to produce 7.7Mln lbs of U_3O_8. Niger and Mamibia together are expected to be producing 65Mln lbs U_3O_8 by 2020.

Kazakhstan has been an important source of uranium for more than 50 years and is known to have approximately 15% of the world resources, the second largest resource behind Australia. Since 2001, production has steadily increased to 30Mlbs U_3O_8 in 2009 from 5Mlbs. Further developments are under way targeting annual production of 35Mlbs in 2010 and 60Mlbs by 2015.

However, this production growth will require a much higher uranium price to make Kazakhstan's second and third generation In Situ Leach (ISL) uranium projects economical. We estimate that cost-push inflation at an annual rate of 15-18% since 2000 and deepening deposits has increased reagents costs (sulphuric acid) significantly. To put this production capability into perspective; we estimate KazAtomProm is able to produce up to 30Mln lbs per yr of U_3O_8 at an average cash cost of $40-45/lb, but increasing annual production a further 15-20% requires a price above $60/lb; further expansion to 45 Mln-plus lbs per yr requires a price above $70/lb.

The dominant producer within the country is State-owned KazAtomProm, which has at least part ownership in all the mines, but numerous joint ventures have been established in recent years with leading uranium producers Cameco, Uranium One, AREVA, consortiums of Japanese companies, Russia's ARMZ, and China's CGNPC.

Approximately 50 uranium deposits are known in six provinces of Kazakhstan. Reasonably Assured Resources (RAR), including Inferred Resources (at a cash costs of $50/lb U_3O_8) total about 2.5Bln lbs U_3O_8.

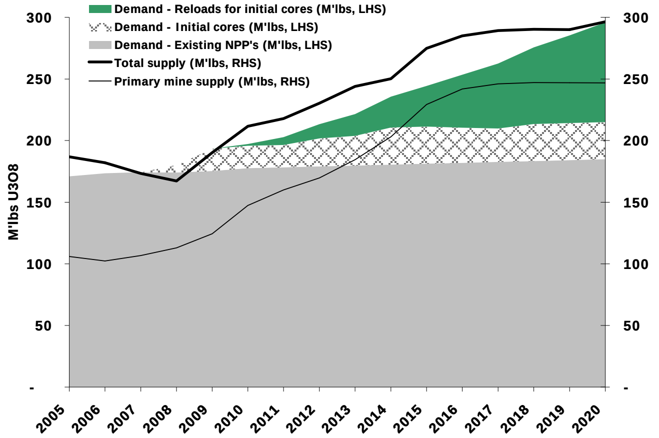
Production from world uranium mines supply account for only 64% of the requirements of power utilities. The balance comes from secondary sources. Secondary supply is essentially inventories of various types and includes inventories held by utilities and other fuel cycle companies, inventories held by governments, used reactor fuel that has been reprocessed, recycled materials from military nuclear programs, and uranium in depleted uranium stockpiles.

Since 1985, Western world uranium production has been less than Western world utility uranium consumption. The resulting shortfall has been covered by a number of secondary sources. Excess inventories held by utilities, producers, other fuel cycle participants, and governments (including Russian government inventories) have been and continue to be a significant source of supply, but availability is declining. Recycled products include reprocessed uranium, mixed oxide fuel, and re-enriched tails material. Some utilities use reprocessed uranium and plutonium derived from used reactor fuel as a source of supply. In recent years, another source of supply has been the use of excess Russian enrichment capacity to re-enrich depleted uranium tails held by European enrichers. Finally, highly enriched uranium (HEU) derived from the dismantling of Russian nuclear weapons has become a significant source of supply equivalent to a large mine. A limited amount of uranium from the U.S. weapons program has been introduced into the market but is not expected to become a significant supply source. With the exception of recycled material, secondary supplies are finite and will be depleted over the next few years. The key exception, Russian HEU, will continue to supply annual quantities to the Western market for many years.

Major End Markets

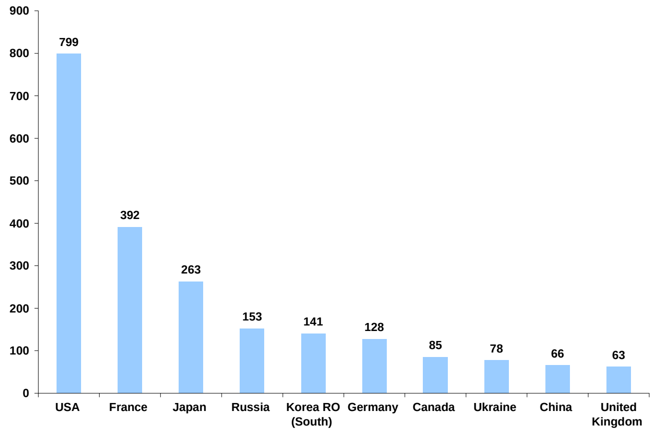
The demand for uranium concentrate (U_3O_8) is directly linked to the level of electricity generated by nuclear power plants. Therefore, our long-term growth assumption for uranium demand is roughly the same as our assumption of nuclear electricity generating capacity: roughly 2-3%. Our assumption attempts to take into account changes in the factors that can affect the characteristics of uranium production requirements, such as reactor design, load factors, enrichments levels, fuel burn efficiency, and cycle length. We estimate that total global uranium demand will be about 210 million pounds in 2010, rising to 226 million pounds by 2012 and 295 million pounds by 2020.

Exhibit 151: **Uranium Supply and Demand**



Source: World Nuclear Association, Credit Suisse estimates.

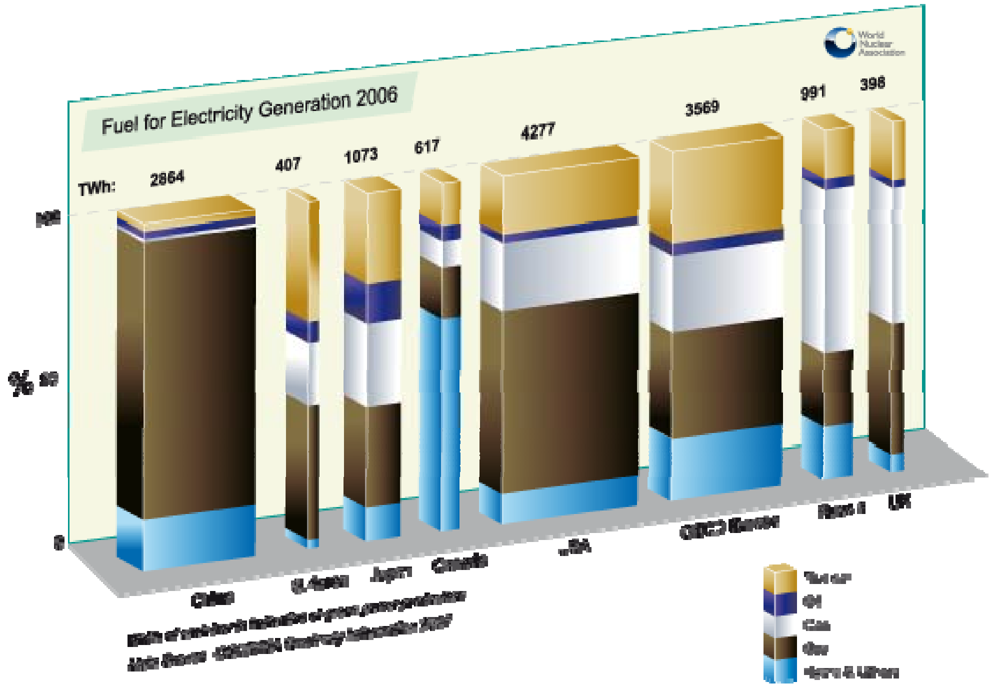
Exhibit 152: **Top 10 Nuclear Electricity Generators (KWh)**



Source: World Nuclear Association, Credit Suisse estimates.

According to data from the WNA, China plans to increase its nuclear power capacity to 80 GWe by 2020 from 10.2GWe currently. By our estimate, China will need an additional 110 million pounds of equivalent uranium concentrate for its initial core and 55 million pounds thereafter as its maintenance requirement. This amount compares with current production capacity of only 2.2 million pounds. China's backbone of uranium mining and metallurgy has historically been located in its Guangdong, Jiangxi, and Hunan provinces. However, in recent years, uranium exploration has been focused on northwest and north China, where there is potential for expansion of uranium mining.

Exhibit 153: Fuel for Electricity Generation (%)



Source: World Nuclear Association.

Steel

Steel

The following is a summarized version of our Steel Primer, which we published separately. For the full report, please see A Steel Primer*, published January, 2011.*

What is Steel?

Steel is basically the end result of refined iron, typically including other elements or alloys to produce different types of steel for various applications. Standard carbon steel contains 97% iron and 0.05-1.25% carbon. Alloys such as nickel, molybdenum, chromium, manganese, and silicon can be added to make steel stronger, malleable, and corrosion resistant, etc. Coating steel with zinc, aluminum, tin, terne, and/or paint further enhances the quality and/or appearance of certain types of steel.

Crude (raw) steel is the first solid state after melting and is suitable for further processing or sale. Raw steel is typically hard and brittle. Higher carbon content enhances the hardness of steel, but increases the brittleness as well. The high degree of brittleness is not a desirable property as far as industrial requirements are concerned. It is therefore alloyed with other metals, each of which imparts special properties to the steel.

The various types of steel (and alloys) along with the properties and uses are highlighted in Exhibit 154.

Exhibit 154: Types of Steel

Type of Steel	Properties	Typical Applications
Carbon Steels		
Low-Carbon (0.07 – 0.25%)	Reduced hardness and brittleness, ease of cold-molding	Car bodies (doors, bonnets, etc)
Medium Carbon (0.25–0.5%)	Higher wear resistance	Rails and rail products: couplings, crank shafts, axles, gears, forgings
Carbon Tool Steel (0.85–1.2%)	Strength and wear resistance	Cutting tools, rails
Cast Iron (2.5 - 3.8%)	High degree of brittleness, ease of casting	Pistons and cylinders (dues to ease of casting)
Alloy Steels (specialized steel)		
Cobalt Steel	High magnetic permeability	Magnets
Manganese	Strength and hardness	Heavy duty rail crossings
Molybdenum	High strength even at high temperatures	High speed drill tips
Nickel and Chromium	Corrosion resistance	Surgical instruments
Titanium	Increased hardness and tensile strength	High speed tool steels, permanent magnets
Tungsten	High melting point and toughness	Cutting and drilling tools
Vanadium	Superior strength and hardness	Tools

Source: Credit Suisse.

How to Make Steel

Five Steps to Making Steel

1. **Raw material treatment**: purifying coal into a high-carbon fuel called coke.
2. **Iron-making**: burning coke in a blast furnace to melt iron ore. At the same time, using limestone to eliminate impurities in the ore, resulting in a high-iron-content product called pig iron.
3. **Steel-making**: combining molten pig iron with steel scrap in a basic oxygen furnace to remove most of the remaining carbon from the pig iron, thus producing steel.
4. **Casting**: casting the steel into a semifinished shape.
5. **Rolling and finishing**: rolling semifinished products into a variety of finished shapes.

Two Production Processes

Production is primarily undertaken through two different processes:

1. Integrated Steel Plants (ISPs)
2. Electric Arc Furnaces (EAF's, typically known as minimills)

Steel can be made from either iron ore or from recycled scrap steel.

Integrated steel mills use a method known as the basic oxygen furnace method (BOF) to produce steel, while mini-mills use the electric arc furnace method (EAF). The BOF method consumes metallurgical coal in the form of coke, whereas the EAF method employs electricity to remelt scrap steel as its primary feedstock to produce steel. Minimills do not consume metallurgical coal.

In an electric arc furnace, steel is made from using steel scrap in place of iron ore, and by following steps three to five above.

The iron-making portion of the steel production process (i.e., step two) is the most energy intensive. As such, steel produced via the minimill process, which does not use a basic oxygen furnace, is generally less energy and GHG (Greenhouse Gas) intensive than steel production from an integrated steel mill.

Normally, EAFs are smaller than BOFs, and are characterized by higher productivity and lower overhead costs relative to BOFs. EAFs typically offer a higher degree of flexibility with regard to production levels when compared with BOFs. However, EAF production is highly dependant on availability of scrap steel and electricity, as these two inputs typically account for 75%-plus of EAFs' total operating costs. As such, the economic benefits of the EAF versus BOF production process are also dependent upon geographic location, with proximity to scrap steel and low-cost electricity important components. The United States is one of world's largest EAF steel-producing countries owing to an abundance of steel scrap and the availability of relatively inexpensive electricity.

The BOF method accounts for approximately 71% of global steel production, while the EAF method accounts for approximately 28% (the remaining 1% of steel output is produced using various other production methods). EAFs have represented the fastest growing segment of steel production technology, increasing market share to 28% from approximately 15% during the past few decades.

Historically, integrated steel mills produced a higher-quality end product when compared with minimills, as the use of scrap steel in a minimill typically created certain imperfections and impurities not found in the integrated production process.

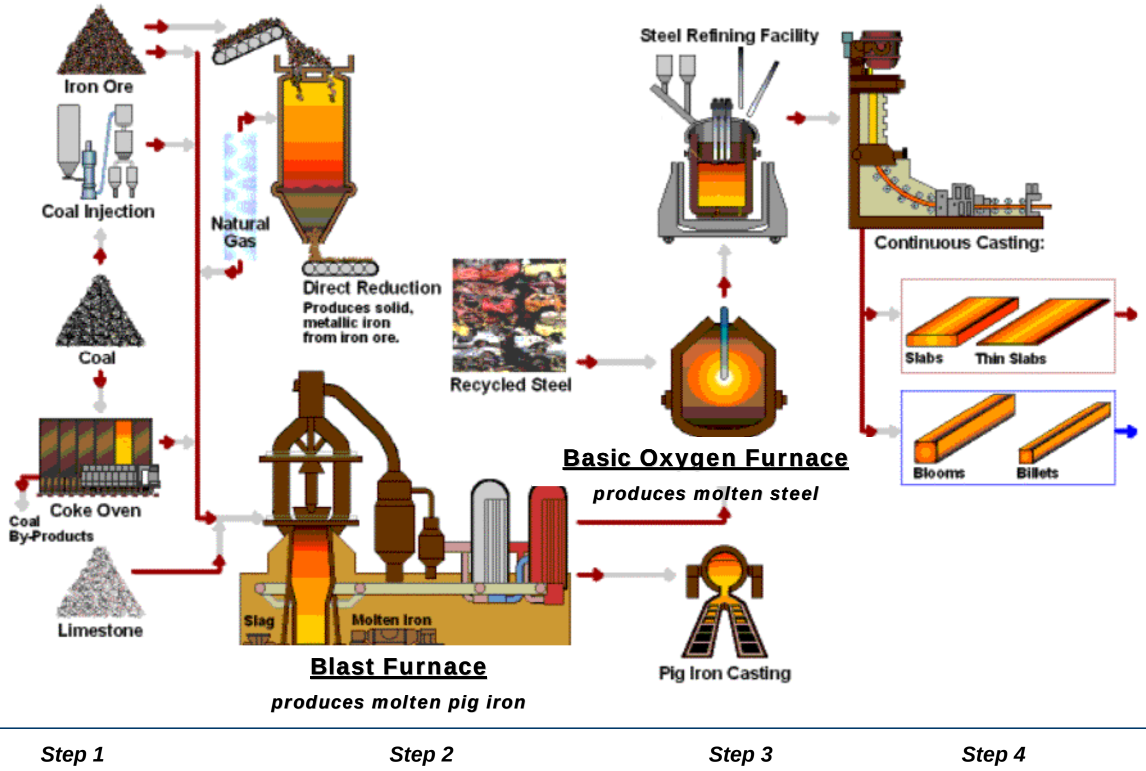
Historically, minimills typically used almost 100% scrap as input into the furnace, while the integrated producers typically used 10-25% scrap in the production process.

However, the growth of minimills caused an increase in global scrap prices, which in turn led to research for substitutes of scrap, mostly produced from virgin iron ore that could be used by minimills to produce a better steel quality. The most popular scrap substitutes are direct reduced iron (DRI), hot briquetted iron (HBI), and Iron Dynamics (IDI).

Scrap substitutes and technology improvements in the minimill production process have also improved the quality of finished steel product from EAFs, allowing minimills to become increasingly competitive with integrated producers at various points in the steel product value chain.

Steel-Making Process

Exhibit 155: **The Integrated Steel Making Process—Flow line (Steps 1–4)***



**Note: the minimill process essentially starts at Step 3 and replaces the BOF with an electric arc furnace.*

Source: American Iron and Steel Institute.

Step 1—The Raw Material Recipe

The raw materials used to make steel in the integrated production process are iron ore, metallurgical coal (in the semifinished form of coke), and limestone.

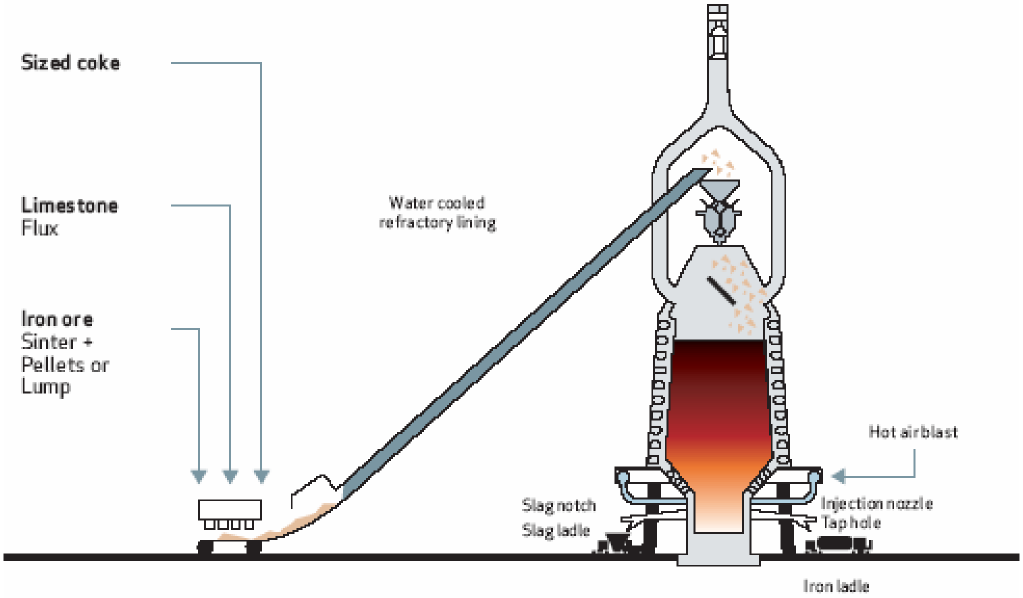
- Mix 1¾ tons of iron ore, ¾ ton of coke, ¼ ton of limestone, and 4 tons of air to produce 1 ton of pig iron in a blast furnace.
- Iron ore typically has varied iron content and needs to be concentrated to 60%-70% iron content through a process of crushing, roasting, magnetic separation, or chemical/gravitational flotation.

- To allow good airflow around the ore during the process of pig iron reduction in the blast furnace, iron ore is aggregated into pellets or briquettes before being used in steelmaking.
- To make coke, metallurgical coal is baked in coke ovens (i.e., a coke battery) at 1,650-2,000 degrees Fahrenheit to eliminate water and impurities, converting metallurgical coal into almost a pure carbon state. In the blast furnace, the ore is piled onto the coke. As such, the coke needs to be structurally strong to allow for appropriate air circulation after the ore burden is piled onto the coke.

Step 2—Iron-Making in the Blast Furnace

- In the blast furnace, a continuous jet of preheated air is used to allow the coke to burn intensely at a temperature of about 3,500 degrees Fahrenheit. The intense heat breaks down the iron ore and creates carbon monoxide. The carbon monoxide absorbs the oxygen contained in the iron oxide ore and transforms into carbon dioxide, which is then exhausted. The residual is pig iron, a form of purer iron in a liquid state that remains at the bottom of the furnace.

Exhibit 156: **Basic Oxygen Furnace**



Source: World Coal Institute.

- At the bottom of the blast furnace, the molten limestone attracts residual impurities in the cooking ore and floats them to the top of the bath of molten pig iron forming in the bottom of the furnace. This limestone layer is called slag and attracts certain elements while repelling others, as those elements precipitate out of the molten solution.
- When a considerable quantity of molten pig iron has accumulated at the bottom of the blast furnace, a tap hole is opened and the pig iron is poured into vessels for further processing, while the slag follows a different route for other markets.

Step 3—Steel-Making in the BOF or EAF

Basic Oxygen Furnace

- In the traditional way of making steel (integrated route), pig iron, containing 3-4% carbon, is refined further to make steel. Typically, molten pig iron is poured into a Basic Oxygen Furnace (BOF), where the carbon content is reduced to approximately 0.5-1.25% by adding limestone (to remove impurities). Scrap steel is also added to serve as a coolant.

- In a BOF, oxygen is blown at speeds up to Mach 2.3 through a long tube inserted into the furnace. Upon oxidization of carbon and silicon in the mixture, a very high heat is released, and the scrap steel melts into the molten mass. The oxygen serves to remove the carbon.

- After oxygen is blown into the BOF for about 20 minutes, slag is poured off the top of the molten bath in one direction, and the steel is poured in the other direction onto a huge ladle where the chemistry and quality of steel is controlled with more accuracy.

- A number of variations/adjustments have been applied to the basic oxygen furnace process. Examples include using pulverized coal injection (PCI) as a substitute for more expensive higher quality metallurgical coals in the coke-making process. Adjustments of how much scrap is used, how material is charged into the furnace, etc., can all be made to enhance efficiencies and/or to mitigate energy costs in a weak market, or conversely refine the process to produce more steel (albeit slightly more expensive) in a strong market.

Electric Arc Furnace

- The mini-mill process essentially eliminates steps one and two above, and in step 3, an electric arc furnace replaces a basic oxygen furnace. An electric arc furnace does not use hot metal, but instead is charged with cold material, typically scrap steel.

- Scrap steel is first loaded into the electric arc furnace from an overhead crane. A lid containing three graphite electrodes is then lowered into the electric arc furnace. An electric current is passed through the electrodes to form an arc. The heat created from this arc then melts the scrap steel. Typically during the melting process, other metals are added to the steel to adjust for the required chemical composition. Oxygen is also blown into the furnace to purify the steel.

Step 4—Casting

- After achieving the required chemistry, molten steel is poured from a ladle into either a mold-casting operation to produce an ingot, or more often, into a continuous caster to produce a slab, billet, or bloom. During this process, the molten steel is typically cooled and transformed into a semisolid state (solid on the outside, still liquid on the inside). The resulting product is referred to as semifinished.

- An ingot is simply a block of steel whose size can vary up to the size of a car, resulting from cooling of liquid steel inside a mold. Once obtained, the cast ingot can be reheated until the heat reaches a uniform temperature throughout the steel and processed further through rerolling or breakdown into the common semifinished shapes of slab, billet, or bloom.

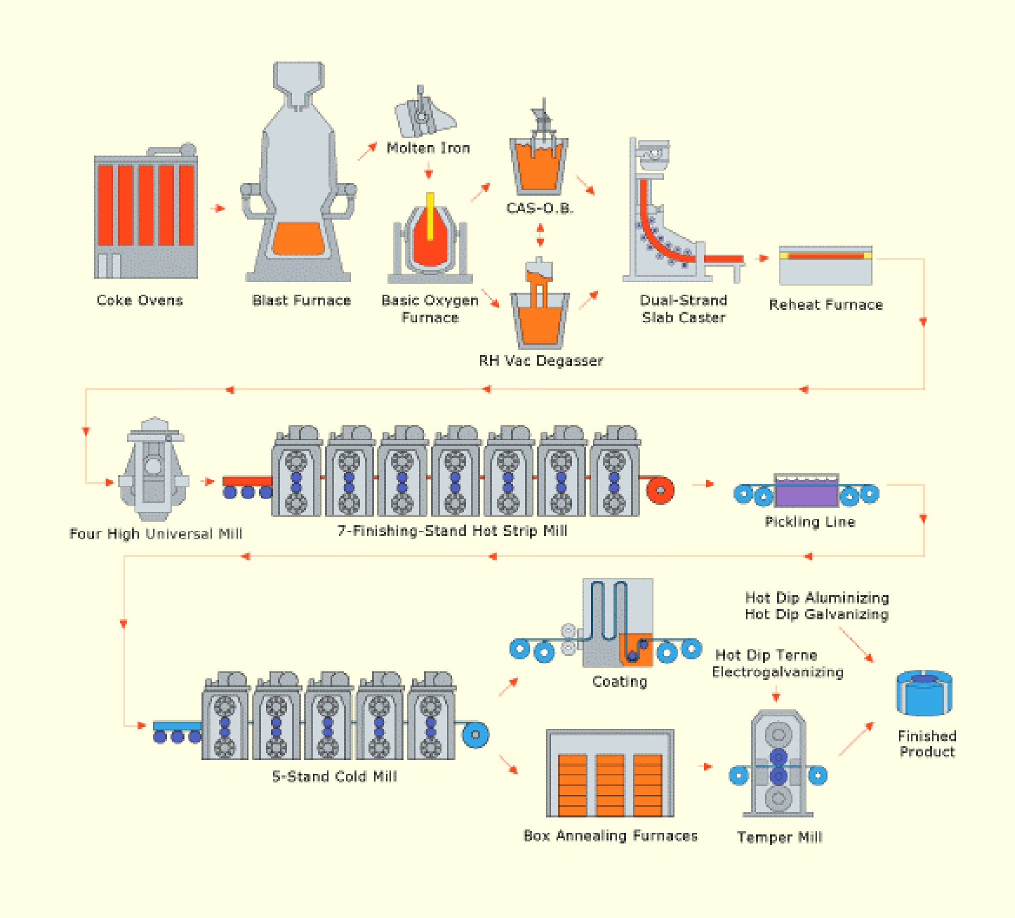
- A slab is the semifinished product used to make flat rolled steel products such as plate and sheet. Slabs have a rectangular cross section typically 4-12 inches thick and 3-5 feet across, though some reach widths of 10½ feet. A slab normally looks like a long mattress. Thin slabs are only two inches thick. Slabs are then rolled (i.e., compressed), and transformed into flat products, either plate (rolled steel that is more than 3/16 of an inch thick) or sheet (rolled steel that is less than 3/16 of an inch thick). The benefit of starting with thinner slabs is that it typically requires less rolling to reduce to the required thinness and therefore is less expensive.

- A billet is the semifinished product used to make long products such as bar, rod, wire, rails, structural beams, and seamless pipe. Billets have a square cross section typically 2-6 inches on a side. A bloom is an oversized billet with a cross-sectional area greater than 36 square inches and is the typical semifinished material for larger long products.

Step 5—Rolling and Finishing

- Depending on the specifications of the required finished product end use, semifinished products are further rolled or pinched into a finished product, either flat (i.e., sheet, plate, etc.) or long (i.e., rebar, beams, rails etc.).

Exhibit 157: Rolling and Finishing—Step 5



Source: AK Steel.

Types of Steel Products

Flat Rolled Products

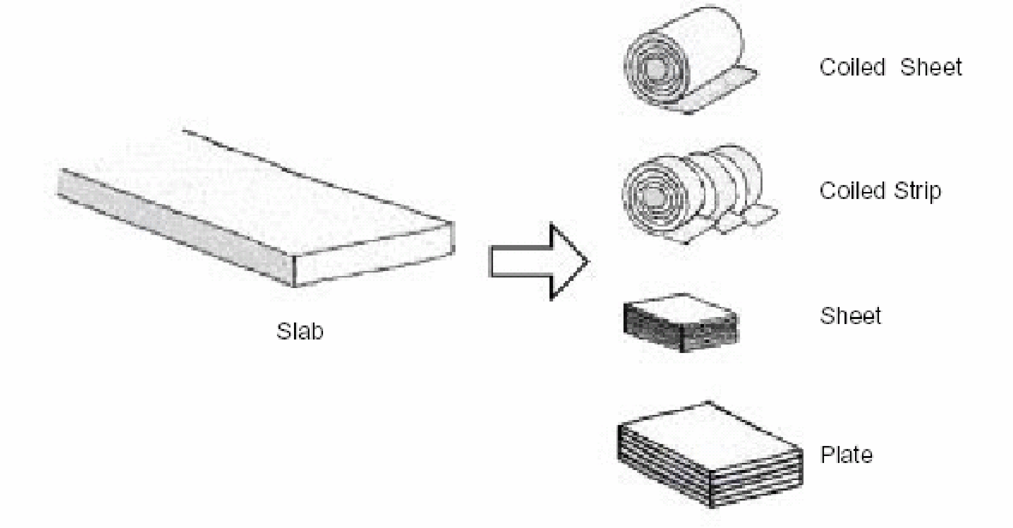
The hot rolling process is the reduction of slab thickness, after reheating and softening, through an enormous pressure applied by stands of rolls in the rolling mill (similar concept as rolling dough). The slab thickness can be reduced from 4-12 inches down to 0.10-2 inches while its length can go from 30-40 feet up to one-half mile.

Scale breakers, descalers, roughers, or scarfers are the various types of machines used to prepare slabs for hot rolling by removing impurities on the slab as it moves through the rollers. After rolling, the hot rolled product can be coiled, or cut into sheets and plates.

The classification of flat rolled products into sheets and plates depends on the thickness of the product: usually, under 3/16 of an inch thick is considered sheet; while over 3/16 of an inch is classified as plate. A strip is a sheet that is less than 2 feet wide. Hot rolled coils represent the commodity-grade product of semifinished flat rolled steel.

Hot rolled products can be further processed into cold rolled products, coated, or formed and used for tubes and pipes production.

Exhibit 158: Flat Rolled Products and Their Precursor Slab



Source: VirtualSteel 2000.

Hot Rolled Coil (HRC)
Hot rolled steel can be shipped as it is (black band), cleaned and shipped (hot band), or rolled further into thinner gauges without reheating (cold rolled). Hot rolled steel is further cleaned in the pickling process, which cleans the surface of the steel by running the steel through an acid bath to remove the black oxide scale formed during the hot rolling process.

Cold Rolled Coil (CRC)
Cold rolled steel is a flat product in which the required final thickness is obtained by rolling the steel at room temperature. In cold rolling, the hot rolled coil is rolled into thinner gauges through further passage in rolling stands. Cold rolled steel possesses a better surface, enhanced strength, and better dimensional characteristics than hot rolled steel. While hot rolled steel typically has a thickness of 0.30-0.50 inches, cold rolled steel usually has a thickness of 0.08-0.13 inches.

Before processing into cold rolled steel, it is necessary to pickle the steel to eliminate the black oxide scale on the surface. The steel is then annealed, which involves slow heating and cooling to improve ductility.

Coated Steel

Applying a coating to steel significantly enhances the quality and/or appearance of certain types of steel. Coatings typically include zinc, aluminum, tin, terne, and/or paint.

Zinc Coating or Galvanizing

A layer of zinc can be put on steel by a hot dip or electrolytic bath. In the hot-dip process, the steel is immersed into a zinc bath until the desired coating of zinc is achieved. In the electrolytic galvanizing process, an electric charge is put on the steel that bonds zinc to the steel's surface. Electro-galvanizing is more expensive than hot-dip galvanizing, and therefore, has ceded market share to hot dip. Besides being less costly, hot-dip galvanizing also provides a relatively greater degree of control over the zinc coating layers.

Typical applications for galvanized zinc are automobiles (underbody parts), air ductwork, roofing and siding, garbage cans, metal building panels, and metal studs (light), or electrical boxes, casings for light fixtures, bumpers, grain bins, and highway guard rails (heavy).

Tin-Coated Steel, or Tinplate

A layer of tin can be applied to steel, typically via an electrolytic process. Tin mill products are used by the container industry in the manufacturing of cans, ends, and closures for the food and beverage industry because of their high corrosion resistance properties and ability to impart less metallic taste to food.

Terne-Coated Sheet

Terne-coated sheet is created by dipping steel in a bath of molten terne metal (a lead and tin alloy). Terne-coated sheet accounts for a relatively small portion of the overall steel market, but it has performance characteristics useful in applications such as fuel tanks and air cleaners.

Painted Steel

Steel can also be painted, typically after applying a zinc or tin coating. Examples of painted steel applications include roofing, siding, gutters, interior cabinets, and appliances. Steel painting technology allows for more bending in painted steel without cracks and greater coating properties.

Plate

Plate products are hot-rolled products that are over 3/16 of an inch thick. Plates are used for ship-building, construction, large-diameter welded pipes, and boiler applications.

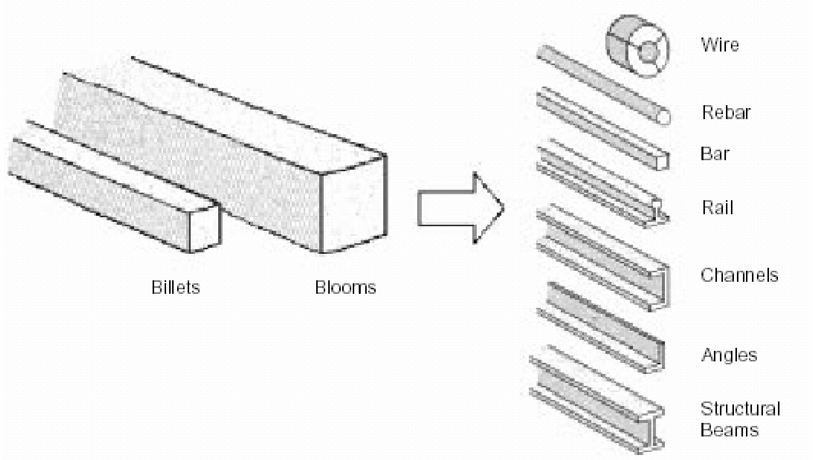
Flat Rolled Pipe and Tube Products

Pipes and tubes can be made from steel sheet or plate. A strip of steel is bent into a tube and welded lengthwise (or twisted into a continuous spiral and edge welded) to form welded pipe and welded tubing. Applications for welded pipes include standard plumbing. Electric-resistance welded (ERW) pipe, which is larger in diameter, is typically found in natural gas distribution lines.

Long Rolled Products

Long products are made by pushing billets and blooms through rollers that pinch and push the steel into different cross-sectional shapes. Finished output is typically bars, rails, structurals, rounds, angles, piling, channels, Z-angles, and hex shapes.

Exhibit 159: Long products and Their Precursors—Billets and Blooms



Source: VirtualSteel.

The four main categories of long products are rebar, merchant bar (MBQ), special bar quality bar (SBQ), and structurals.

Rebar

Rebar is a round bar with hash-mark indentations along the side and is primarily used for reinforcing concrete in construction and infrastructure applications. Rebar is more of a commodity than other bar products, making price the primary competitive factor. The majority of rebar in the United States is made from scrap via the minimill process.

Merchant Bar (MBQ)

Merchant bar includes long bars with round, square, flat, angled, and channeled cross sections. Approximately 25% of the market is represented by joists, the largest end use for merchant shapes, 13% by other applications, 10% by mine bolts, and the remaining 50% includes a wide range of construction and industrial equipment, material handling, and transportation. Similar to rebar, merchant bar in the United States is primarily made from scrap via the minimill process.

Special Bar Quality (SBQ)

Bars with high and consistent metallurgical qualities are called SBQs. They are short diameter bars and are often used for making drawn wire. Applications may include motor shafts, engine bolts, screws, rivets, wrenches, bolts, springs, cable wire, chains, tire beads, and welding wire. Key industrial sectors for SBQ application are automotive, oil and gas, agricultural equipment, and capital goods.

Long-Rolled Pipe and Tube

Seamless pipe and tube is made by piercing a rotating heated bloom or billet with a long-armed, pointed piece of steel called a mandrel. Rollers can further work the pipe into a longer pipe with a shorter diameter.

Seamless tubing is used in process industries and boiler tubing. Special grades and longer diameters of pipe and tube go into oil country tubular goods (OCTG) and are necessary for down-hole oil and gas drilling activity.

Specialty Steels

Specialty steels are defined by their alloy content, which changes the physical qualities of steel. Stainless steel, for example, not only has carbon steel's qualities of strength, durability and malleability, but also resists corrosion in many harsh environments, maintains its strength at high operating temperatures, and provides an attractive, easily maintained surface appearance.

Stainless Steel

Stainless steel is typically produced by melting stainless steel scrap in an electric arc furnace and is therefore minimill based. The stainless steel production process is more batch-oriented than continuous-oriented when compared with the typical carbon steel production process. The stainless steel market is a relatively small subset of the overall steel market, representing approximately 2-3% of global steel output (by volume).

Stainless steel can be divided in Ferritic and Austenitic grades. Austenitic grades are the most commonly used stainless steels, accounting for more than 70% of global production of stainless steel. Austenitic-grade stainless steel usually contains 4-35% nickel and 16-26% chromium. Austenitic grades have wider applications and uses than ferritic grades, but are more expensive to produce owing to the higher nickel content. Austenitic-grade stainless steel is typically used for applications such as food processing equipment, flatware, kitchen sinks, and chemical plant equipment.

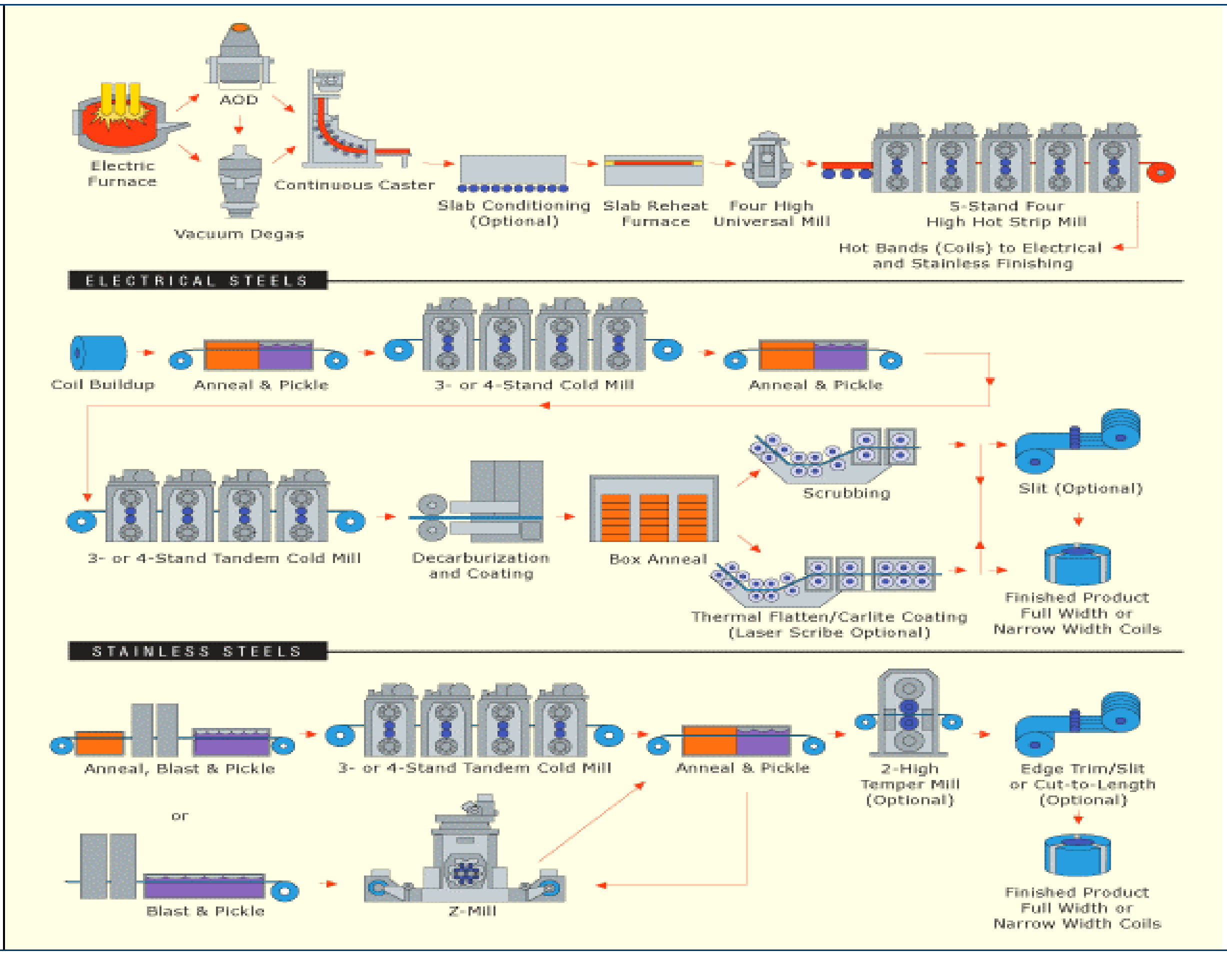
Ferritic-grade stainless steels typically contain 10-18% chromium and have no nickel content. Ferritic-grade stainless is typically used for items such as vehicle trim, auto exhaust systems, catalytic converters, and hot water tanks.

Electrical Steel

Electrical steel is also made by some producers of stainless steel. Electrical steel is classified as specialty steel owing to the absence of chrome. Electrical steel can be divided into grain-oriented (GO) and nonoriented. The former is treated in a way to align the atomic structure, which enhances conductivity and lowers resistance and heat generation. Grain-oriented steel is typically used in transformers at power stations (25% of the GO market share) and distribution centers (50% market application) of the electric utility grid. GO demand is primarily dependant on housing starts and utility capital spending.

Nonoriented electric steel is electric steel where the atomic structure or grains are not necessarily aligned. Nonoriented electrical steel is mainly used in electric motors and appliances.

Exhibit 160: Stainless and Electrical Steel Production Flow Line


Electric Furnace
AOD
Vacuum Degas
Continuous Caster
Slab Conditioning (Optional)
Slab Reheat Furnace
Four High Universal Mill
5-Stand Four High Hot Strip Mill
Hot Bands (Coils) to Electrical and Stainless Finishing
ELECTRICAL STEELS
Coil Buildup
Anneal & Pickle
3- or 4-Stand Cold Mill
Anneal & Pickle
Scrubbing
Slit (Optional)
3- or 4-Stand Tandem Cold Mill
Decarburization and Coating
Box Anneal
Thermal Flatten/Carlite Coating (Laser Scribe Optional)
Finished Product Full Width or Narrow Width Coils
STAINLESS STEELS
Anneal, Blast & Pickle
3- or 4-Stand Tandem Cold Mill
Anneal & Pickle
2-High Temper Mill (Optional)
Edge Trim/Slit or Cut-to-Length (Optional)
or
Blast & Pickle
Z-Mill
Finished Product Full Width or Narrow Width Coils

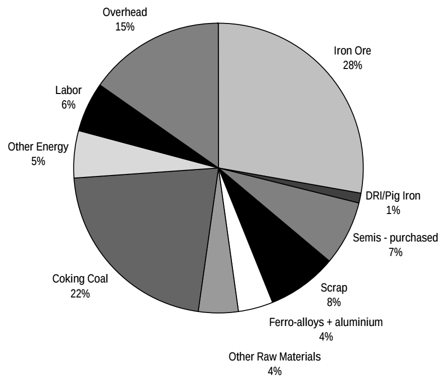
Source: AK Steel.

Components of Steel Costs

The cost of making steel depends on the production method used (integrated process versus minimill process). The integrated process utilizes less scrap, which results in higher-quality steel but typically is higher cost. Conversely, minimill production uses primarily scrap steel, which translates into a relatively lower cost of production.

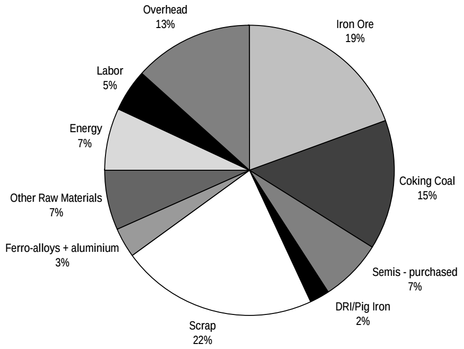
The two biggest components involved in producing steel via the integrated production process are iron ore and coking coal, which together comprise approximately 50% of total costs for standard hot rolled coil production. Conversely, for minimill producers', the single largest cost component is scrap steel (20-50% of total), although iron ore and coking coal also represent a significant portion of total costs (i.e., approximately 20% of the total).

Exhibit 161: **Global Average Production Costs—HRC**



Source: Metal Bulletin.

Exhibit 162: **Global Average Production Costs— Bars**



Source: Metal Bulletin.

Key Steel-Making Raw Materials

For the integrated production process, steel is created primarily by mixing of pig iron with steel scrap. One ton of pig iron is created from 1¾ tons of iron ore, ¾ ton of coke, ¼ ton of limestone, and 4 tons of air.

Iron Ore

Iron ore comprises roughly 5% of the earth's crust. Iron is the primary ingredient in the steel-making process, with roughly 98% of all iron ore mined earmarked for steel-making. Ores containing iron include magnetite and hematite, which contain roughly 70% and 72% iron, respectively. In the United States, iron is found in taconite, which typically contains 30% magnetite and hematite, and can be concentrated to 60-70% iron content through a process of crushing and roasting, magnetic separation, or chemical/ gravitational flotation. Concentrated iron ore is then formed into pellets, which are the most common form of processed iron ore used in steel-making. Roughly 95% of usable ore (Taconite) in the United States comes from Michigan and Minnesota.

Coke

Coke is made by baking metallurgical coal in ovens at 1,650-2,000 degrees Fahrenheit. This process removes water and impurities in the coal, in order to obtain an almost pure form of carbon that is lightweight but still structurally strong to avoid being crushed by the iron ore's weight in the blast furnace. The coke also becomes more porous, which enables proper airflow in the cooking section.

Limestone

Limestone is a key ingredient in step two of the pig iron process, and is continuously conveyed and poured, or charged, together with coke and iron ore, into the top of the blast furnace. As the ingredients sift and sink to the bottom of the furnace, the heat breaks down the virgin iron ore while the carbon monoxide attracts the oxygen from the iron oxide ore to form carbon dioxide, which exhausts. The residue is a purer iron material known as pig iron, which regroups in a liquid state at the bottom of the furnace.

In the lower portion of the blast furnace, molten limestone attracts other impurities in the cooking ore and floats them on the bath of molten pig iron forming in the bottom of the furnace. The limestone layer is called slag, which attracts certain elements and repels others, as those elements precipitate out of the molten solution.

Scrap Steel

Scrap is required by both integrated and minimill steel producers. It is the primary input for minimills and accounts for approximately 10-40% of the basic oxygen furnace inputs in the integrated process. While there are no direct substitutes for iron ore in the integrated process, in times of low scrap prices, integrated producers will try to use more scrap in place of iron ore to reduce costs.

Scrap steel supply/demand is typically affected by similar supply/demand drivers of finished steel, although scrap steel has its own individual supply/demand (and hence pricing) patterns. Also, because scrap can act as a substitute for iron ore, the prices of the two commodities generally move in the same direction over time.

Scrap can be classified in two different grades.

Low Residual Scrap

Low residual scrap can be classified in five different grades. No. 1 bushlings are steel scrap of any dimension under one foot. They include sheet clippings and stampings and typically result from waste trim material from steel product fabrication. Low residual scrap steel does not include old auto stock or coated material. Black sheet clippings are basically waste originated by hot rolled material processing, no longer than 8 feet by 18 inches. No. 1 bundles are compressed scrap or hand bundled, including chemically detinned material. Shredded clippings consist of scrap cut into smaller pieces and include recovered steel from automobiles, unprepared No. 1 steel, and miscellaneous scrap.

Home scrap is the last source of lower residual scrap and is internally generated by a steel company and includes side trim, end trim, and poor-quality production recycled back into the melt system.

Obsolete Scrap

Obsolete scrap comes from a variety of peddlers, auto dismantlers, and minor smaller machine shops as well as railroads, demolition projects, and shipyards. The different obsolete scrap steel production processes include shredding, chopping, or bundling.

Scrap Substitutes and New Technologies

Direct Reduced Iron (DRI)

Direct reduced iron is the creation of iron from iron ore via heating and chemical reduction by natural gas as opposed to in a blast furnace. Direct reduced iron is typically more expensive than reducing iron ore in a blast furnace, but at the same time it is richer in iron than pig iron (i.e., 97% pure iron versus 93% for molten pig iron). For a minimill, DRI serves as a feedstock, allowing the minimill to use lower grades of scrap steel for the remaining portion of the steel production inputs.

Circofer and Circored

Circofer and Circored are reduced-iron processes that utilize fluidized bed reactors to reduce iron ore fines. Coal is the fuel needed for the Circofer process, while Circored utilizes natural gas.

Corex

The Corex process combines an iron melter/coal gasifier vessel with a prereduction shaft to produce a liquid product that is similar to blast furnace hot metal. Coal, oxygen, and prereduced iron are fed into the melter/gasifier to melt the iron and produce a highly reduced gas.

Fastmet

The Fast-Metalization process forms pellets from iron ore fines and pulverized coal. The process is fast, as pellets are transformed into metallic ore in a few minutes, through placement in a rotary hearth furnace that dries them up and reduce them into metal for 90-95%.

The advantage is that this process uses cheaper coal instead of natural gas, while the drawback is that a lot of attention has to be paid while shipping the material, as it is very sensitive to water (it can burn owing to its instability) and because it contains more sulfur and phosphorus when compared with standard reduced iron products.

Iron Dynamics

The Iron Dynamics (IDI) process implies the formation of a cake of coal and iron ore fines, which is subsequently passed through a rotary hearth. Although this process is fast (it can be completed in a few minutes), it too contains more sulfur, which is removed through another cooking step in a customized arc furnace that is electric-energy based.

Iron Carbide

This process directly reduces iron by using hydrogen and natural gas, instead of coal. The iron carbide system extracts oxygen and impurities from the ore and leaves iron and carbon. The outcome is 80-90% iron carbide (Fe_3C), which contains 8% carbon. Iron carbide is stable enough for shipping and does not need to be formed into pellets. The extra carbon contained in iron carbide can be used to produce heat in the arc furnace, which reduces electricity needs. Iron carbide could also replace up to 25% of the scrap input in an electric furnace, although it would be necessary to install additional injection equipment.

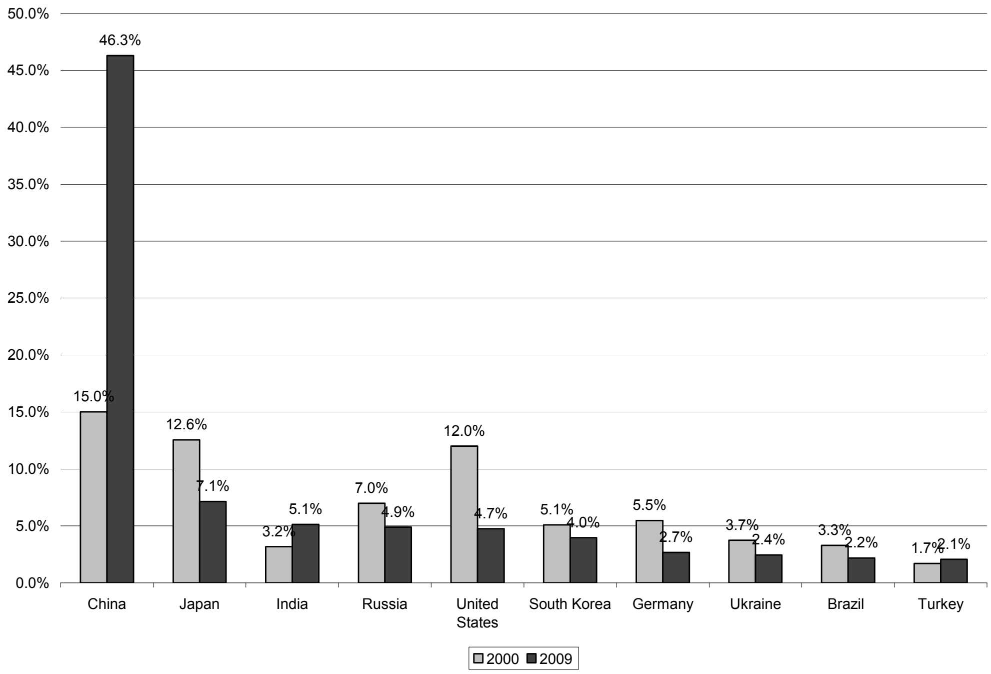
Other

Other processes include DIOS (two-stage furnace, coal based, uses fines, Japan); Hismelt (shaft furnace, coal based, uses fines); HYL (shaft furnace, natural gas based, pellets or lump ore, Hylsa); Inmetco (natural-gas-fired rotary hearth furnace, pelletized iron ore with coal, Inco); Midrex (shaft furnace, natural gas based, pellets or lump ore); Purofer (shaft furnace, natural gas, lump ore, Thyssen-Hutte); and SL/RN (tilted rotary hearth furnace, coal based, lump ore or pellets, international joint venture).

Sources of Supply

Geographically, the emergence of China as the driver of industrial growth in the past decade has resulted in significant demand and production growth. China's market share of global crude steel production increased to 46.3% in 2009 from 15.0% in 2000.

Exhibit 163: Top Global Steel Producers by Country (% of Total Production)



Source: World Steel Association.

In terms of individual producers, as of the end of 2009, the steel industry was still fragmented, with the 20 largest global players controlling approximately 34% of global crude steel production. By way of comparison, the top ten copper producers in 2010 controlled approximately 50% of global mine supplies.

Exhibit 164: Top 20 Global Steel Producers (Based on 2009 Output)

Company	Production	% of Global Production
ArcelorMittal	77.5	6.32%
Baosteel	31.3	2.55%
POSCO	31.1	2.53%
Nippon Steel	26.5	2.16%
JFE	25.8	2.10%
Jiangsu Shagang	20.5	1.67%
Tata Steel	20.5	1.67%
Ansteel	20.1	1.64%
Severstal	16.7	1.36%
Evraz	15.3	1.25%
US Steel	15.2	1.24%
Shougang	15.1	1.23%
Gerdau Group	14.2	1.16%
Nucor	14.0	1.14%
Wuhan	13.7	1.12%
SAIL	13.5	1.10%
Handan	12.0	0.98%
Riva	11.3	0.92%
Sumitomo	11.0	0.90%
ThyssenKrupp	11.0	0.90%
Total	**416.3**	**33.93%**

In million metric tons. Source: World Steel Association.

Companies Mentioned *(Price as of 12 Jan 11)*
Alcoa Inc. (AA, $16.24, OUTPERFORM [V], TP $21.00)
Alpha Natural Resources (ANR, $66.38, NEUTRAL [V], TP $59.00)
Anglo American plc (AAL.L, 3396.50 p, OUTPERFORM [V], TP 4000.00 p, OVERWEIGHT)
Antofagasta (ANTO.L, 1571.00 p, UNDERPERFORM [V], TP 1560.00 p, OVERWEIGHT)
ArcelorMittal (MT.N, $35.18, OUTPERFORM [V], TP $49.00, OVERWEIGHT)
Barrick Gold Corp. (ABX, $50.00, OUTPERFORM, TP $63.00)
BHP Billiton (BLT.L, 2550.00 p, NEUTRAL, TP 3000.00 p, OVERWEIGHT)
Chalco Aluminum Corp of China Ltd, A-Share (601600.SS, Rmb10.18)
Cloud Peak Energy (CLD, $23.08, OUTPERFORM, TP $32.00)
CONSOL Energy Inc. (CNX, $54.00, OUTPERFORM [V], TP $60.00)
Dow Chemical Company (DOW, $35.85, OUTPERFORM [V], TP $44.00)
Freeport-McMoRan Copper & Gold (FCX, $121.84, OUTPERFORM [V], TP $155.00)
Gold Fields Limited (GFIJ.J)
Hindustan Zinc Limited (HZNC.BO, Rs1414.95, OUTPERFORM, TP Rs1300.00)
Jiangxi Copper Company Ltd (0358.HK, HK$26.95, NEUTRAL [V], TP HK$21.80)
KGHM Polska Miedz S.A. (KGHM.WA, PLN178.20, NEUTRAL [V], TP PLN165.00)
Massey Energy Company (MEE, $58.04, NEUTRAL [V], TP $60.00)
Minmetals Resources Ltd. (1208.HK, HK$5.49)
Mitsubishi Materials (5711, ¥267, OUTPERFORM, TP ¥310, OVERWEIGHT)
Newmont Mining (NEM, $57.79, OUTPERFORM, TP $80.00)
Nucor (NUE, $44.73, OUTPERFORM, TP $52.00)
Rio Tinto Limited/PLC (RIO.L, 4542.50 p, OUTPERFORM [V], TP 6000.00 p, OVERWEIGHT)
Southern Copper Corporation (SCCO, $47.26, OUTPERFORM [V], TP $58.00)
Sumitomo Metal Mining (5713, ¥1,413, OUTPERFORM, TP ¥1,500, OVERWEIGHT)
Teck Resources Ltd. (TCKb.TO, C$64.24, OUTPERFORM [V], TP C$74.00)
United States Steel Group (X, $56.63, NEUTRAL [V], TP $55.00)
Vale (VALE, $36.61, OUTPERFORM [V], TP $47.00)
Vedanta Resources PLC (VED.L, 2514.00 p, RESTRICTED [V])
Wacker Chemie (WCHG.DE, Eu134.35, NEUTRAL [V], TP Eu142.00, MARKET WEIGHT)
Xstrata Plc (XTA.L, 1535.00 p, OUTPERFORM [V], TP 2000.00 p, OVERWEIGHT)

Disclosure Appendix

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